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INTERPOLATION PROCESSING APPARATUS AND RECORDING MEDIUM HAVING INTERPOLATION PROCESSING PROGRAM RECORDED THEREIN

[Scope of Patent Claims]

[Claim 1]

An interpolation processing apparatus that engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, comprising:

a means for interpolation value calculation that uses color information at nearby pixels located nearby an interpolation target pixel to undergo interpolation processing to calculate an interpolation value including, at least

(1) a first term indicating local average information with regard to the first color component

(2) a second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel and

(3) a third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel.

[Claim 2]

An interpolation processing apparatus according to claim 1, further comprising:

a first means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions in which nearby pixels with color information corresponding to the first color component are connected with the interpolation target pixel; and

a second means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions other than the directions in which the degrees of similarity are judged by said first means for similarity judgment, wherein:

said means for interpolation value calculation selects a direction along which nearby pixels having color information to be used to calculate said first term and said second term are set based upon results of a judgment made by said first means for similarity judgment; and

said means for interpolation value calculation selects a direction along which nearby pixels having color information to be used to calculate said third term are

set based upon results of a judgment made by said second means for similarity judgment.

[Claim 3]

An interpolation processing apparatus that engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, comprising:

a means for interpolation value calculation that calculates an interpolation value including at least two terms, i.e., a first term and a second term by using color information at nearby pixels set nearby an interpolation target pixel to undergo interpolation processing;

a first means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions in which nearby pixels having color information corresponding to the first color component are connected to the interpolation target pixel; and

a second means for similarity judgment that judges degrees of similarity to the interpolation target pixel

along at least two directions other than the directions in which the degrees of similarity are judged by said first means for similarity judgment, wherein:

said means for interpolation value calculation selects a direction along which pixels having color information to be used to calculate said first term are set based upon results of a judgment made by said first means for similarity judgment and selects a direction along which pixels having color information to be used to calculate said second term are set based upon results of a judgment made by said second means for similarity judgment.

[Claim 4]

An interpolation processing apparatus according to claim 3, wherein

said means for interpolation value calculation calculates a first term containing local average information with regard to the first color component and curvature information with regard to a color component matching a color component at the interpolation target pixel, and a second term containing curvature information with regard to a color component other than the color component at the interpolation target pixel to calculate the interpolation value.

[Claim 5]

An interpolation processing apparatus according to

claim 2, wherein:

when image data are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel;

said first means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees;

said second means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two diagonal directions in which nearby pixels

with color information corresponding to the third color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and

said means for interpolation value calculation selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second means for similarity judgment when calculating said third term.

[Claim 6]

An interpolation processing apparatus according to claim 5, wherein:

said means for interpolation value calculation calculates the third term based upon color information corresponding to the first color component if said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the third term based upon color information corresponding to the third color component if said second means for similarity judgment judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal

direction.

[Claim 7]

An interpolation processing apparatus according to claim 3, wherein:

when image data are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel;

said first means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees;

said second means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two diagonal directions in which nearby pixels with color information corresponding to the third color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and

said means for interpolation value calculation selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second means for similarity judgment when calculating said second term.

[Claim 8]

An interpolation processing apparatus according to claim 7, wherein:

said means for interpolation value calculation calculates the second term based upon color information corresponding to the first color component if said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the second based upon color information corresponding to the third color component if

said second means for similarity judgment judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal direction.

[Claim 9]

An interpolation processing apparatus according to claim 5 or 7, wherein:

said first means for similarity judgment judges that roughly equal degrees of similarity manifest along the vertical direction and the horizontal direction if a difference between the similarity degrees along the vertical direction and the horizontal direction is smaller than a specific threshold value; and

said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions if a difference between the similarity degrees along the two diagonal directions is smaller than a specific threshold value.

[Claim 10]

An interpolation processing apparatus according to claim 5 or 7, wherein:

said first means for similarity judgment calculates the similarity degrees along the vertical direction and the horizontal direction by using color information corresponding to a plurality of color components for a

single interpolation target pixel; and

said second means for similarity judgment calculates the similarity degrees along the two diagonal directions by using color information corresponding to a plurality of color components for a single interpolation target pixel.

[Claim 11]

An interpolation processing apparatus according to claim 10, wherein:

said second means for similarity judgment calculates a similarity degree manifesting along each of the two diagonal directions through weighted addition of:

(1) a similarity degree component constituted of color information corresponding to the first color component alone;

(2) a similarity degree component constituted of color information corresponding to the second color component alone;

(3) a similarity degree component constituted of color information corresponding to the third color component alone; and

(4) a similarity degree component constituted of color information corresponding to the second color component and the third color component.

[Claim 12]

An interpolation processing apparatus according to

claim 5 or 7, wherein:

said first means for similarity judgment calculates similarity degrees along the vertical direction and the horizontal direction for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel; and

said second means for similarity judgment calculates similarity degrees along the two diagonal directions for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the two diagonal directions based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel.

[Claim 13]

An interpolation processing apparatus that engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component

is missing, comprising:

a means for first term calculation that calculates a first term representing average information of the first color component with regard to an interpolation target pixel to undergo interpolation processing by using color information corresponding to color components at nearby pixels set nearby the interpolation target pixel;

a means for second term calculation that calculates a second term representing local curvature information with regard to a color component matching the color component at the interpolation target pixel by using color information corresponding to color components at pixels each containing a color component same as the interpolation target pixel; and

a means for interpolation value calculation that calculates an interpolation value by adding said second term multiplied by a weighting coefficient constituted of color information corresponding to a plurality of color components at nearby pixels and the interpolation target pixel to said first term.

[Claim 14]

An interpolation processing apparatus according to claim 13, wherein:

said means for interpolation value calculation uses color information corresponding to a plurality of color

components provided at the interpolation target pixel and at a plurality of pixels set along a predetermined direction relative to the interpolation target pixel to ascertain inclinations manifesting in color information corresponding to the individual color components along the direction and calculates said weighting coefficient in conformance to a correlation manifesting among the inclinations in the color information corresponding to the individual color components.

[Claim 15]

An interpolation processing apparatus that implements processing for supplementing a color component value at a pixel at which information corresponding to a color component is missing in image data provided in a colorimetric system constituted of a luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and the luminance component present both at pixels having information corresponding to the color component and at pixels lacking information corresponding to the color component, comprising:

a means for hue value calculation that calculates hue values at a plurality of pixels located near an interpolation target pixel to undergo interpolation processing and having both the luminance component and the

color component by using luminance component values and color component values at the individual pixels;

a means for hue value interpolation that calculates a hue value at the interpolation target pixel by using a median of the hue values at the plurality of pixels calculated by said means for hue value calculation; and

a means for color conversion that interpolates a color component at the interpolation target pixel by using the luminance component at the interpolation target pixel to convert the hue value at the interpolation target pixel calculated by said means for hue value interpolation to a color component.

[Claim 16]

An interpolation processing apparatus that implements processing for supplementing a luminance component at a pixel at which information corresponding to a luminance component is missing and supplementing a color component at a pixel at which information corresponding to a color component is missing, on image data provided in a colorimetric system constituted of the luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and a given pixel having only information corresponding to either the luminance component or the color component, comprising:

a means for luminance component interpolation that interpolates a luminance component at a luminance component interpolation target pixel to undergo luminance component interpolation processing by using at least either "similarity manifesting between the luminance component interpolation target pixel and a pixel near the luminance component interpolation target pixel" or "a plurality of color components within a local area containing the luminance component interpolation target pixel";

a means for hue value calculation that calculates hue values at a plurality of pixels located near an interpolation target pixel to undergo color component interpolation processing, having color component values and having luminance component values interpolated by said means for luminance component interpolation, by using the luminance component values and color component values at the individual pixels;

a means for hue value interpolation that calculates a hue value for the interpolation target pixel by using a median of the hue values at the plurality of pixels calculated by said means for hue value calculation; and

a means for color conversion that interpolates a color component value for the interpolation target pixel by using the luminance component value at the

interpolation target pixel to convert the hue value at the interpolation target pixel calculated by said means for hue value interpolation to a color component value.

[Claim 17]

An interpolation processing apparatus according to claim 15 or 16, wherein:

when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component,

said means for hue value interpolation calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels near the interpolation target pixel if the green color component is present but the red color component is missing at the interpolation target pixel and calculates a hue value for the interpolation target pixel by using a median of hue values containing the blue color component at pixels near the interpolation target pixel if the green color component is present but the blue color component is missing at the interpolation target pixel.

[Claim 18]

An interpolation processing apparatus according to claim 15 or 16, wherein:

when the luminance component in the image data

corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component,

said means for hue value interpolation calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels set near the interpolation target pixel if the blue color component is present but the red color component is missing at the interpolation target pixel.

[Claim 19]

An interpolation processing apparatus according to claim 15 or 16, wherein:

when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component,

said means for hue value interpolation calculates a hue value for the interpolation target pixel by using a median of hue values containing the blue color component at pixels set near the interpolation target pixel if the red color component is present but the blue color component is missing at the interpolation target pixel.

[Claim 20]

An interpolation processing apparatus according to any one of claims 15 through 19, with a color component

missing at the interpolation target pixel present at only one pixel among four pixels set symmetrically along the vertical direction and the horizontal direction, wherein said means for hue value interpolation comprises:

a first hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a plurality of diagonally adjacent pixels if the hue values of the plurality of diagonally adjacent pixels adjacent to the interpolation target pixel along diagonal directions have been calculated by said means for hue value calculation; and

a second hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a plurality of vertically and horizontally adjacent pixels if the hue values of the plurality of vertically and horizontally adjacent pixels adjacent to the interpolation target pixel in the vertical direction and the horizontal direction have been calculated by said means for hue value calculation or said first hue value interpolation unit.

[Claim 21]

A recording medium having recorded therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first

color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components with color information corresponding to a single color component present at each pixel, said interpolation processing program comprising:

an interpolation value calculation step in which an interpolation value including, at least

(1) a first term indicating local average information with regard to the first color component

(2) a second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel and

(3) a third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel.

[Claim 22]

A recording medium having recorded therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components with color information corresponding to a single color component present at each pixel, said interpolation processing program comprising:

an interpolation value calculation step in which an interpolation value including at least two terms, i.e., a first term and a second term is calculated by using color information at nearby pixels set nearby an interpolation target pixel to undergo interpolation processing;

a first similarity judgment step in which degrees of similarity to the interpolation target pixel are judged along at least two directions in which nearby pixels having color information corresponding to the first color component are connected with the interpolation target pixel; and

a second similarity judgment step in which degrees of similarity to the interpolation target pixel are judged along at least two directions other than the directions along which the degrees of similarity are judged in said first similarity judgment step, wherein:

in said interpolation value calculation step, a direction in which pixels having color information to be used to calculate said first term are set is selected based upon results of a judgment made in said first similarity judgment step and a direction in which pixels having color information to be used to calculate said second term are set is selected based upon results of a judgment made in said second similarity judgment step.

[Claim 23]

A recording medium having recorded therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components with color information corresponding to a single color component present at each pixel, said interpolation processing program comprising:

a first term calculation step in which a first term representing average information of the first color component with regard to an interpolation target pixel to undergo interpolation processing is calculated by using color information corresponding to a color component at nearby pixels set nearby the interpolation target pixel;

a second term calculation step in which a second term representing local curvature information with regard to a color component matching the color component at the interpolation target pixel is calculated by using color information corresponding to a color component at pixels each containing a color component same as the interpolation target pixel; and

an interpolation value calculation step in which an interpolation value is calculated by adding said second term multiplied by a weighting coefficient constituted of

color information corresponding to a plurality of color components provided at nearby pixels and the interpolation target pixel to the first term.

[Claim 24]

A recording medium having recorded therein an interpolation processing program for implementing on a computer processing supplementing a color component value at a pixel at which information corresponding to a color component is missing, on image data provided in a colorimetric system constituted of a luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and the luminance component present both at pixels having information corresponding to the color component and at pixels lacking information corresponding to the color component; said interpolation processing program comprising:

a hue value calculation step in which hue values for a plurality of pixels near an interpolation target pixel to undergo interpolation processing and having information corresponding to both the luminance component and the color component are calculated by using luminance component values and color component values at the individual pixels;

a hue value interpolation step in which a hue value

for the interpolation target pixel is calculated by using a median of the hue values at the plurality of pixels calculated in the hue value calculation step; and

a color conversion step in which a color component value at the interpolation target pixel is interpolated by using a value indicated by the luminance component present at the interpolation target pixel to convert the hue value of the interpolation target pixel calculated in the hue value interpolation step to a color component value.

[Claim 25]

A recording medium having recorded therein an interpolation processing program for implementing on a computer processing for supplementing a luminance component value at a pixel at which information corresponding to a luminance component is missing and a color component value at a pixel at which information corresponding to a color component missing, on image data provided in a colorimetric system constituted of the luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and information corresponding to either the luminance component or the color component present at each pixel, said interpolation processing program comprising:

a luminance component interpolation step in which a

luminance component value is interpolated for a luminance component interpolation target pixel to undergo luminance component interpolation processing by using at least either "similarity between the luminance component interpolation target pixel and a pixel near the luminance component interpolation target pixel" or "information corresponding to a plurality of color components within a local area containing the luminance component interpolation target pixel";

a hue value calculation step in which hue values at a plurality of pixels located near an interpolation target pixel to undergo color component interpolation processing, having color component values and having luminance component values interpolated in said luminance component interpolation step are calculated by using the luminance component values and color component values at the individual pixels;

a hue value interpolation step in which a hue value for the interpolation target pixel is calculated by using a median of the hue values at the plurality of pixels calculated in the hue value calculation step; and

a color conversion step in which a color component value is interpolated for the interpolation target pixel by using the luminance component value at the interpolation target pixel to convert the hue value at the

interpolation target pixel calculated in said hue value interpolation step to a color component value.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an interpolation processing apparatus that engages in interpolation processing on color image data to supplement a color component and a luminance component missing in pixels and a recording medium having an interpolation processing program for achieving the interpolation processing on a computer, that can be read by a computer.

[0002]

[Prior Art]

Some electronic cameras generate color image data by employing an image-capturing sensor having three color (R, G and B: red, green and blue) color filters provided at specific positions (e.g., a Bayer array). In such an electronic camera in which the individual pixels at the image-capturing sensor each output color information corresponding to only a single color component, it is necessary to implement interpolation processing to obtain color information corresponding to all the color components for each pixel.

[0003]

In an interpolation processing method proposed in the prior art, spatial similarity manifested by an

interpolation target pixel undergoing the interpolation processing is judged and an interpolation value is calculated by using the color information output from pixels positioned along the direction in which a high degree of similarity is manifested.

For instance, in the art disclosed in USP No. 5,629,734, a green color interpolation value G5 for the interpolation target pixel is calculated through one formula among formula 1 through formula 3 when the color information corresponding to individual pixels is provided as shown below, with A5 representing the color information at the interpolation target pixel (a pixel with the green color component missing), A1, A3, A7 and A9 representing color information from pixels provided with color filters in the same color as the color of the filter at the interpolation target pixel and G2, G4, G6 and G8 representing color information from pixels provided with green color filters.

[0004]

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      A1
      G2
A3 G4 A5 G6 A7
      G8
      A9
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If a marked similarity manifests along the horizontal

direction, the green color interpolation value G5 for the interpolation target pixel is calculated through;

G5=(G4+G6)/2+(-A3+2A5-A7)/4 … (formula 1).

If a marked similarity manifests along the vertical direction, the green color interpolation value G5 for the interpolation target pixel is calculated through;

G5=(G2+G8)/2+(-A1+2A5-A9)/4 … (formula 2).

If roughly equal degrees of similarity manifest along the horizontal direction and the vertical direction, the green color interpolation value G5 for the interpolation target pixel is calculated through

G5=(G2+G4+G6+G8)/4+(-A1-A3+4A5-A7-A9)/8 … (formula 3).

It is to be noted that in order to simplify the subsequent explanation, the first terms ((G4 + G6)/2, (G2 + G8)/2) in formulae 1 and 2 are each referred to as a primary term and that second terms ((-A3 + 2A5 -A7)/4 , (-A1 + 2A5 - A9)/4) in formulae 1 and 2 are each referred to as a correctional term.

[0005]

In USP No. 5,629,734, assuming that the image data undergoing the interpolation processing manifest marked similarity along the horizontal direction with A3, G4, A5, G6 and A7 provided as indicated with ● marks in FIG. 15, A4 representing the average of A3 and A5, and A6 representing the average of A5 and A7, the value of the

correctional term in formula 1 is equivalent to the vector quantity (α in FIG. 15) representing the difference between A5 and the average of A4 and A6. In addition, the green color interpolation value G5 is equivalent to a value achieved by correcting the average of the values indicated by the color information from pixels adjacent along the horizontal direction (corresponds to the value of the primary term in formula 1) by α.

[0006]

In other words, in the art disclosed in USP No. 5,629,734, a green color interpolation value is calculated by assuming that the color difference between the green color component and the color component (the red color component or the blue color component) at the interpolation target pixel is constant ((A4-G4), (A5-G5) and (A6-G6) in FIG. 15 match) and correcting the average of the values indicated by the color information from the pixels that are adjacent along the direction in which a high degree of similarity is manifested with color information corresponding to the same color component as that of the interpolation target pixel.

[0007]

[Problems to be solved by the Invention]

Optical systems such as lenses are known to manifest magnification chromatic aberration. For instance, if

there is magnification chromatic aberration at the photographic lens of an electronic camera having an image-capturing sensor provided with color filters in three colors, i.e., R, G and B, arranged in a Bayer array, images corresponding to the red color component and the blue color component are formed at positions slightly offset from the position at which the image corresponding to the green color component is formed, as shown in FIG. 16.

[0008]

If the photographic lens is free of any magnification chromatic aberration and color information corresponding to the individual pixels is provided as indicated by the ● marks in FIG. 17 (1) (the image data undergoing the interpolation processing manifest marked similarity along the horizontal direction, the color information corresponding to the green color component indicates a constant value and the values indicated by the color information corresponding to the red color component and the color information corresponding to the blue color component both change gently in the vicinity of the interpolation target pixel (the pixel at which A5 is present), the value of the correctional term in formula 1 is 0 and, as a result, the average of G4 and G6 (the primary term) is directly used as the green color

interpolation value G5 without correction.

[0009]

However, when A3, A5 and A7 each represent color information corresponding to the red color component and each set of color information corresponding to the red color component is offset by one pixel to the right due to a magnification chromatic aberration at the photographic lens, the color information from the individual pixels undergoes a change as shown in FIG. 17 (2). Consequently, the value of the correctional term in formula 1 is not 0 and the primary term is over-corrected (hereafter referred to as an "over-correction") in such a case, resulting in the green color interpolation value G5 that should be similar to the values indicated by G4 and G6 becoming larger than the G4 and G6 values (hereafter this phenomenon is referred to as an "overshoot"). If, on the other hand, A3, A5 and A7 each represent color information corresponding to the blue color component and each set of color information corresponding to the blue color component is offset by one pixel to the left due to a magnification chromatic aberration, the color information from the individual pixels undergoes a change as shown in FIG. 17 (3). Thus, the value of the correctional term in formula 1 is not 0, resulting in the green color interpolation value G5 that should be similar to the G4

and G6 values becoming smaller than those corresponding to G4 and G6 (hereafter this phenomenon is referred to as an "undershoot") through an over-correction.

[0010]

In other words, the art disclosed in USP No. 5,629,734 poses a problem in that color artifacts occur in the color image obtained through the interpolation processing due to a magnification chromatic aberration.

An over correction also occurs at a color boundary where the color difference changes as well as when there is a magnification chromatic aberration. For instance, the color information corresponding to the individual pixels is provided as indicated by the ● marks in FIG. 18 (1) and (2) (when the color information corresponding to the green color component is constant and the values identified by the color information corresponding to the red color component or the blue color component change drastically near the interpolation target pixel (the pixel at which A5 is present)), the value of the correctional term in formula 1 is not 0 and, an overshoot or an undershoot occurs due to an over correction with regard to the green color interpolation value G5, which should be similar to the values indicated by G4 and G6.

[0011]

Thus, in a color boundary where the color difference

changes, a color artifact occurs as a result of interpolation processing even if there is no magnification chromatic aberration. It is to be noted that such a color artifact as that described above may occur when calculating a red color interpolation value or a blue color interpolation value as well as when calculating a green color interpolation value.

[0012]

An object of the present invention according to claims 1 through 18 is to provide an interpolation processing apparatus capable of preventing occurrence of color artifacts and an object of the present invention according to claims 19 through 23 is to provide a recording medium having recorded therein an interpolation processing program with which occurrence of color artifacts can be prevented.

More specifically, an object of the present invention according to claims 1 through 14 and 19 through 21 is to suppress the occurrence of color artifacts by reducing the problems of the prior art while retaining the advantages of the interpolation processing in the prior art and reducing the degree of the adverse effect of magnification chromatic aberration.

[0013]

[Means for solving the Problems]

An interpolation processing apparatus according to claim 1 engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, and comprises a means for interpolation value calculation that uses color information at nearby pixels located nearby an interpolation target pixel to undergo interpolation processing to calculate an interpolation value including, at least

(1) a first term indicating local average information with regard to the first color component

(2) a second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel and

(3) a third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel.

[0014]

Namely, the invention according to claim 1 calculates an interpolation value by correcting the "first term indicating local average information with regard to the

first color component" with the "second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel" and the "third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel".

An interpolation processing apparatus according to claim 2 is achieved by that, in the interpolation processing apparatus according to claim 1, there are further provided a first means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions in which nearby pixels with color information corresponding to the first color component are connected with the interpolation target pixel, and a second means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions other than the directions in which the degrees of similarity are judged by said first means for similarity judgment; said means for interpolation value calculation selects a direction along which nearby pixels having color information to be used to calculate said first term and said second term are set based upon results of a judgment made by said first means for similarity judgment; and said means for interpolation value calculation selects a direction along

which nearby pixels having color information to be used to calculate said third term are set based upon results of a judgment made by said second means for similarity judgment.

[0015]

Namely, in the invention according to claim 2, since directions along which the second means for similarity judgment judges degrees of similarity are different from directions along which the first means for similarity judgment judges degrees of similarity, a direction along which color information to be used to calculate the first term and the second term exists does not agree with a direction along which color information to be used to calculate the third term exists.

Therefore, according to the invention of claim 2, the interpolation value can be calculated by using color information at nearby pixels located along a plurality of directions. Also, according to the invention of claim 2, the first term through the third term can be calculated by using color information at nearby pixels set along the direction in which a high degree of similarity is manifested or through weighted synthesis of color information from nearby pixels located along a plurality of directions, which is performed in correspondence to varying degrees of similarity.

[0016]

An interpolation processing apparatus according to claim 3 engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, and comprises: a means for interpolation value calculation that calculates an interpolation value including at least two terms, i.e., a first term and a second term by using color information at nearby pixels set nearby an interpolation target pixel to undergo interpolation processing; a first means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions in which nearby pixels having color information corresponding to the first color component are connected to the interpolation target pixel; and a second means for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions other than the directions in which the degrees of similarity are judged by said first means for similarity judgment, and said means for interpolation value calculation selects a direction along which pixels

having color information to be used to calculate said first term are set based upon results of a judgment made by said first means for similarity judgment and selects a direction along which pixels having color information to be used to calculate said second term are set based upon results of a judgment made by said second means for similarity judgment.

[0017]

Namely, in the invention according to claim 3, since directions along which the second means for similarity judgment judges degrees of similarity are different from directions along which the first means for similarity judgment judges degrees of similarity, a direction along which color information to be used to calculate the first term exists does not agree with a direction along which color information to be used to calculate the second term exists.

Therefore, according to the invention of claim 3, the interpolation value can be calculated by using color information at nearby pixels located along a plurality of directions. Also, according to the invention of claim 3, the first term and the second term can be calculated by using color information at nearby pixels set along the direction in which a high degree of similarity is manifested or through weighted synthesis of color

information from nearby pixels located along a plurality of directions, which is performed in correspondence to varying degrees of similarity.

[0018]

An interpolation processing apparatus according to claim 4 is achieved by that in the interpolation processing apparatus according to claim 3, said means for interpolation value calculation calculates a first term containing local average information with regard to the first color component and curvature information with regard to a color component matching a color component at the interpolation target pixel, and a second term containing curvature information with regard to a color component other than the color component at the interpolation target pixel to calculate the interpolation value.

[0019]

Namely, the invention according to claim 4 calculates the interpolation value by correcting the "local average information with regard to the first color component" with the "curvature information with regard to a color component matching a color component at the interpolation target pixel" and the "curvature information with regard to a color component other than the color component at the interpolation target pixel".

An interpolation processing apparatus according to claim 5 is achieved by that in the interpolation processing apparatus according to claim 2: when image data are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel; said first means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees; said second means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along

two diagonal directions in which nearby pixels with color information corresponding to the third color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and said means for interpolation value calculation selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second means for similarity judgment when calculating said third term.

[0020]

In the invention according to claim 5, the third color component is present at nearby pixels adjacent to the interpolation target pixel along the two diagonal directions and the similarity judged by the second similarity judgment section is the similarity manifested by the interpolation target pixel along the two diagonal directions.

Therefore, according to the invention of claim 5, the similarity along the diagonal directions can be reflected in the third term by switching between color information corresponding to the first color component and color information corresponding to the third color component to

be used in conformance to the degrees of similarity manifested by the interpolation target pixel along the two diagonal directions when calculating said third term.

[0021]

An interpolation processing apparatus according to claim 6 is achieved by that in the interpolation processing apparatus according to claim 5, said means for interpolation value calculation calculates the third term based upon color information corresponding to the first color component if said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the third term based upon color information corresponding to the third color component if said second means for similarity judgment judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal direction.

[0022]

Namely, in the interpolation processing apparatus according to claim 6, the similarity manifesting along the diagonal directions is reflected with a high degree of reliability when calculating the third term.

An interpolation processing apparatus according to claim 7 is achieved by that in the interpolation processing apparatus according to claim 3: when image data

are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel; said first means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees; said second means for similarity judgment calculates similarity degrees manifested by the interpolation target pixel along two diagonal directions in which nearby pixels with color information corresponding to the third color component are connected to the interpolation target pixel and makes a

judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and said means for interpolation value calculation selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second means for similarity judgment when calculating said second term.

[0023]

In the invention according to claim 7, the third color component is present at nearby pixels adjacent to the interpolation target pixel along the two diagonal directions and the similarity judged by the second similarity judgment section is the similarity manifested by the interpolation target pixel along the two diagonal directions.

Therefore, according to the invention of claim 7, the similarity along the diagonal directions can be reflected in the second term by switching between color information corresponding to the first color component and color information corresponding to the third color component to be used in conformance to the degrees of similarity manifested by the interpolation target pixel along the two diagonal directions when calculating said second term.

[0024]

An interpolation processing apparatus according to claim 8 is achieved by that in the interpolation processing apparatus according to claim 7, said means for interpolation value calculation calculates the second term based upon color information corresponding to the first color component if said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the second based upon color information corresponding to the third color component if said second means for similarity judgment judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal direction.

[0025]

Namely, in the interpolation processing apparatus according to claim 8, the similarity manifesting along the diagonal directions is reflected with a high degree of reliability when calculating the second term.

An interpolation processing apparatus according to claim 9 is achieved by that in the interpolation processing apparatus according to claim 5 or 7: said first means for similarity judgment judges that roughly equal degrees of similarity manifest along the vertical direction and the horizontal direction if a difference

between the similarity degrees along the vertical direction and the horizontal direction is smaller than a specific threshold value; and said second means for similarity judgment judges that roughly equal degrees of similarity manifest along the two diagonal directions if a difference between the similarity degrees along the two diagonal directions is smaller than a specific threshold value.

[0026]

As a result, in the invention according to claim 9, the adverse effect of noise can be reduced in the judgment of the similarity along the two directions, i.e., the vertical direction and the horizontal direction and the similarity manifesting along the two diagonal directions.

An interpolation processing apparatus according to claim 10 is achieved by that in the interpolation processing apparatus according to claim 5 or 7: said first means for similarity judgment calculates the similarity degrees along the vertical direction and the horizontal direction by using color information corresponding to a plurality of color components for a single interpolation target pixel; and said second means for similarity judgment calculates the similarity degrees along the two diagonal directions by using color information corresponding to a plurality of color components for a

single interpolation target pixel.

[0027]

In other words, in the invention according to claim 10, color information corresponding to a plurality of color components is reflected in the judgment of the similarity manifesting along the vertical and horizontal directions and the similarity manifesting along the two diagonal directions.

An interpolation processing apparatus according to claim 11 is achieved by that in the interpolation processing apparatus according to claim 10 said second means for similarity judgment calculates a similarity degree manifesting along each of the two diagonal directions through weighted addition of:

(1) a similarity degree component constituted of color information corresponding to the first color component alone;

(2) a similarity degree component constituted of color information corresponding to the second color component alone;

(3) a similarity degree component constituted of color information corresponding to the third color component alone; and

(4) a similarity degree component constituted of color information corresponding to the second color component

and the third color component.

[0028]

In other words, in the invention according to claim 11, color information corresponding to a plurality of color components is reflected in the judgment of the similarity manifesting along the two diagonal directions.

An interpolation processing apparatus according to claim 12 is achieved by that in the interpolation processing apparatus according to claim 5 or 7: said first means for similarity judgment calculates similarity degrees along the vertical direction and the horizontal direction for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel; and said second means for similarity judgment calculates similarity degrees along the two diagonal directions for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the two diagonal directions based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel.

[0029]

In other words, in the invention according to claim

12, color information corresponding to a plurality of color components is reflected in the judgment of the similarity manifesting along the vertical and horizontal directions and the similarity manifesting along the two diagonal directions.

An interpolation processing apparatus according to claim 13 engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, and comprises: a means for first term calculation that calculates a first term representing average information of the first color component with regard to an interpolation target pixel to undergo interpolation processing by using color information corresponding to color components at nearby pixels set nearby the interpolation target pixel; a means for second term calculation that calculates a second term representing local curvature information with regard to a color component matching the color component at the interpolation target pixel by using color information corresponding to color components at pixels each

containing a color component same as the interpolation target pixel; and a means for interpolation value calculation that calculates an interpolation value by adding said second term multiplied by a weighting coefficient constituted of color information corresponding to a plurality of color components at nearby pixels and the interpolation target pixel to said first term.

[0030]

In other words, in the invention according to claim 13, the interpolation value is calculated by correcting the "average information of the first color component" with the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by a weighting coefficient constituted of color information corresponding to a plurality of color components present at the interpolation target pixel and nearby pixels.

An interpolation processing apparatus according to claim 14 is achieved by that in the interpolation processing apparatus according to claim 13, said means for interpolation value calculation uses color information corresponding to a plurality of color components provided at the interpolation target pixel and at a plurality of pixels set along a predetermined direction relative to the interpolation target pixel to ascertain inclinations

manifesting in color information corresponding to the individual color components along the direction and calculates said weighting coefficient in conformance to a correlation manifesting among the inclinations in the color information corresponding to the individual color components.

[0031]

As a result, in the invention according to claim 14, the "average information of the first color component" is corrected with the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by the weighting coefficient, and the weighting coefficient is calculated in conformance to the correlation among the inclinations of the color information corresponding to the different color components in the area nearby the interpolation target pixel.

[0032]

An interpolation processing apparatus according to claim 15 implements processing for supplementing a color component value at a pixel at which information corresponding to a color component is missing in image data provided in a colorimetric system constituted of a luminance component and the color component, with the luminance component having a higher spatial frequency than

the color component and the luminance component present both at pixels having information corresponding to the color component and at pixels lacking information corresponding to the color component, and comprises: a means for hue value calculation that calculates hue values at a plurality of pixels located near an interpolation target pixel to undergo interpolation processing and having both the luminance component and the color component by using luminance component values and color component values at the individual pixels; a means for hue value interpolation that calculates a hue value at the interpolation target pixel by using a median of the hue values at the plurality of pixels calculated by said means for hue value calculation; and a means for color conversion that interpolates a color component at the interpolation target pixel by using the luminance component at the interpolation target pixel to convert the hue value at the interpolation target pixel calculated by said means for hue value interpolation to a color component.

[0033]

Namely, in the invention according to claim 15, the hue value of the interpolation target pixel is calculated by using the median of the hue values of a plurality of pixels located near the interpolation target pixel.

An interpolation processing apparatus according to claim 16 implements processing for supplementing a luminance component at a pixel at which information corresponding to a luminance component is missing and supplementing a color component at a pixel at which information corresponding to a color component is missing, on image data provided in a colorimetric system constituted of the luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and a given pixel having only information corresponding to either the luminance component or the color component, and comprises: a means for luminance component interpolation that interpolates a luminance component at a luminance component interpolation target pixel to undergo luminance component interpolation processing by using at least either "similarity manifesting between the luminance component interpolation target pixel and a pixel near the luminance component interpolation target pixel" or "a plurality of color components within a local area containing the luminance component interpolation target pixel"; a means for hue value calculation that calculates hue values at a plurality of pixels located near an interpolation target pixel to undergo color component interpolation processing, having color component values

and having luminance component values interpolated by said means for luminance component interpolation, by using the luminance component values and color component values at the individual pixels; a means for hue value interpolation that calculates a hue value for the interpolation target pixel by using a median of the hue values at the plurality of pixels calculated by said means for hue value calculation; and a means for color conversion that interpolates a color component value for the interpolation target pixel by using the luminance component value at the interpolation target pixel to convert the hue value at the interpolation target pixel calculated by said means for hue value interpolation to a color component value.

[0034]

Namely, in the invention according to claim 16, the hue value of the interpolation target pixel is calculated by using the median of the hue values of a plurality of pixels located near the interpolation target pixel.

An interpolation processing apparatus according to claim 17 is achieved by that in the interpolation processing apparatus according to claim 15 or 16, when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component, said means for hue value interpolation

calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels near the interpolation target pixel if the green color component is present but the red color component is missing at the interpolation target pixel and calculates a hue value for the interpolation target pixel by using a median of hue values containing the blue color component at pixels near the interpolation target pixel if the green color component is present but the blue color component is missing at the interpolation target pixel.

[0035]

In other words, in the invention according to claim 17, the hue value of the interpolation target pixel at which the green color component is present but the red color component is missing is calculated by using the median of the hue values containing the red color component from pixels located near the interpolation target pixel, whereas the hue value of the interpolation target pixel at which the green color component is present but the blue color component is missing is calculated by using the median of the hue values containing the blue color component from pixels located near the interpolation target pixel.

[0036]

An interpolation processing apparatus according to

claim 18 is achieved by that in the interpolation processing apparatus according to claim 15 or 16, when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component, said means for hue value interpolation calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels set near the interpolation target pixel if the blue color component is present but the red color component is missing at the interpolation target pixel.

[0037]

Namely, in the invention according to claim 18, the hue value of the interpolation target pixel at which the blue color component is present but the red color component is missing is calculated by using the median of the hue values containing the red color component from pixels located near the interpolation target pixel.

[0038]

An interpolation processing apparatus according to claim 19 is achieved by that in the interpolation processing apparatus according to claim 15 or 16, when the luminance component in the image data corresponds to a green color component and the color component in the image

data corresponds to a red color component and a blue color component, said means for hue value interpolation calculates a hue value for the interpolation target pixel by using a median of hue values containing the blue color component at pixels set near the interpolation target pixel if the red color component is present but the blue color component is missing at the interpolation target pixel.

[0039]

Namely, in the invention according to claim 19, the hue value of the interpolation target pixel at which the red color component is present but the blue color component is missing is calculated by using the median of the hue values containing the blue color component from pixels located near the interpolation target pixel.

An interpolation processing apparatus according to claim 20, in the interpolation processing apparatus according to any one of claims 15 through 19: a color component missing at the interpolation target pixel presents at only one pixel among four pixels set symmetrically along the vertical direction and the horizontal direction; and said means for hue value interpolation comprises a first hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a

plurality of diagonally adjacent pixels if the hue values of the plurality of diagonally adjacent pixels adjacent to the interpolation target pixel along diagonal directions have been calculated by said means for hue value calculation, and a second hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a plurality of vertically and horizontally adjacent pixels if the hue values of the plurality of vertically and horizontally adjacent pixels adjacent to the interpolation target pixel in the vertical direction and the horizontal direction have been calculated by said means for hue value calculation or said first hue value interpolation unit.

[0040]

In other words, in the invention according to claim 20, if the hue values at pixels adjacent along the diagonal directions are already calculated, the hue value of the interpolation target pixel is calculated by using the median of the hue values at the diagonally adjacent pixels, and whereas if the hue values at pixels adjacent in the vertical and horizontal directions are already calculated, the hue value of the interpolation target pixel is calculated by using the median of the hue values at the vertically and horizontally adjacent pixels.

A recording medium according to claim 21 recordes

therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components with color information corresponding to a single color component present at each pixel. The interpolation processing program comprises: an interpolation value calculation step in which an interpolation value including, at least

(1) a first term indicating local average information with regard to the first color component

(2) a second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel and

(3) a third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel.

[0041]

Namely, the invention according to claim 21 calculates an interpolation value by correcting the "first term indicating local average information with regard to the first color component" with the "second term indicating curvature information with regard to a color component matching a color component at the interpolation

target pixel" and the "third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel".

A recording medium according to claim 22 records therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components with color information corresponding to a single color component present at each pixel. The interpolation processing program comprises: an interpolation value calculation step in which an interpolation value including at least two terms, i.e., a first term and a second term is calculated by using color information at nearby pixels set nearby an interpolation target pixel to undergo interpolation processing; a first similarity judgment step in which degrees of similarity to the interpolation target pixel are judged along at least two directions in which nearby pixels having color information corresponding to the first color component are connected with the interpolation target pixel; and a second similarity judgment step in which degrees of similarity to the interpolation target pixel are judged along at least two directions other than the directions

along which the degrees of similarity are judged in said first similarity judgment step, and in said interpolation value calculation step, a direction in which pixels having color information to be used to calculate said first term are set is selected based upon results of a judgment made in said first similarity judgment step and a direction in which pixels having color information to be used to calculate said second term are set is selected based upon results of a judgment made in said second similarity judgment step.

[0042]

Namely, in the invention according to claim 22 since directions along which the second similarity judgment step judges degrees of similarity are different from directions along which the first similarity judgment step judges degrees of similarity, a direction along which color information to be used to calculate the first term exists does not agree with a direction along which color information to be used to calculate the second term exists.

Therefore, according to the invention of claim 22 the interpolation value can be calculated by using color information at nearby pixels located along a plurality of directions. Also, according to the invention of claim 22 the first term and the second term can be calculated by using color information at nearby pixels set along the

direction in which a high degree of similarity is manifested or through weighted synthesis of color information from nearby pixels located along a plurality of directions, which is performed in correspondence to varying degrees of similarity.

[0043]

A recording medium according to claim 23 records therein an interpolation processing program to implement on a computer processing for determining an interpolation value equivalent to color information corresponding to a first color component missing at a pixel, on image data provided in a colorimetric system constituted of first ~ nth (n ≧ 3) color components with color information corresponding to a single color component present at each pixel. The interpolation processing program comprises: a first term calculation step in which a first term representing average information of the first color component with regard to an interpolation target pixel to undergo interpolation processing is calculated by using color information corresponding to a color component at nearby pixels set nearby the interpolation target pixel; a second term calculation step in which a second term representing local curvature information with regard to a color component matching the color component at the interpolation target pixel is calculated by using color

information corresponding to a color component at pixels each containing a color component same as the interpolation target pixel; and an interpolation value calculation step in which an interpolation value is calculated by adding said second term multiplied by a weighting coefficient constituted of color information corresponding to a plurality of color components provided at nearby pixels and the interpolation target pixel to the first term.

[0044]

In other words, in the invention according to claim 23, the interpolation value is calculated by correcting the "average information of the first color component" with the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by a weighting coefficient constituted of color information corresponding to a plurality of color components present at the interpolation target pixel and nearby pixels.

A recording medium according to claim 24 records therein an interpolation processing program for implementing on a computer processing supplementing a color component value at a pixel at which information corresponding to a color component is missing, on image data provided in a colorimetric system constituted of a

luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and the luminance component present both at pixels having information corresponding to the color component and at pixels lacking information corresponding to the color component. The interpolation processing program comprises: a hue value calculation step in which hue values for a plurality of pixels near an interpolation target pixel to undergo interpolation processing and having information corresponding to both the luminance component and the color component are calculated by using luminance component values and color component values at the individual pixels; a hue value interpolation step in which a hue value for the interpolation target pixel is calculated by using a median of the hue values at the plurality of pixels calculated in the hue value calculation step; and a color conversion step in which a color component value at the interpolation target pixel is interpolated by using a value indicated by the luminance component present at the interpolation target pixel to convert the hue value of the interpolation target pixel calculated in the hue value interpolation step to a color component value.

[0045]

Namely, in the invention according to claim 24, the

hue value of the interpolation target pixel is calculated by using the median of the hue values of a plurality of pixels located near the interpolation target pixel.

A recording medium according to claim 25 records therein an interpolation processing program for implementing on a computer processing for supplementing a luminance component value at a pixel at which information corresponding to a luminance component is missing and a color component value at a pixel at which information corresponding to a color component missing, on image data provided in a colorimetric system constituted of the luminance component and the color component, with the luminance component having a higher spatial frequency than the color component and information corresponding to either the luminance component or the color component present at each pixel. The interpolation processing program comprises: a luminance component interpolation step in which a luminance component value is interpolated for a luminance component interpolation target pixel to undergo luminance component interpolation processing by using at least either "similarity between the luminance component interpolation target pixel and a pixel near the luminance component interpolation target pixel" or "information corresponding to a plurality of color components within a local area containing the luminance

component interpolation target pixel"; a hue value calculation step in which hue values at a plurality of pixels located near an interpolation target pixel to undergo color component interpolation processing, having color component values and having luminance component values interpolated in said luminance component interpolation step are calculated by using the luminance component values and color component values at the individual pixels; a hue value interpolation step in which a hue value for the interpolation target pixel is calculated by using a median of the hue values at the plurality of pixels calculated in the hue value calculation step; and a color conversion step in which a color component value is interpolated for the interpolation target pixel by using the luminance component value at the interpolation target pixel to convert the hue value at the interpolation target pixel calculated in said hue value interpolation step to a color component value.

[0046]

Namely, in the invention according to claim 25, the hue value of the interpolation target pixel is calculated by using the median of the hue values of a plurality of pixels located near the interpolation target pixel.

Inventions [1] through [15] related to the above will

be disclosed as follows.

[1] In the recording medium according to claim 22 having recorded therein an interpolation processing program, the interpolation processing program further comprises: a first similarity judgment step that judges degrees of similarity to the interpolation target pixel along at least two directions in which nearby pixels with color information corresponding to the first color component are connected with the interpolation target pixel; and a second step for similarity judgment that judges degrees of similarity to the interpolation target pixel along at least two directions other than the directions in which the degrees of similarity are judged by said first step for similarity judgment. The interpolation value calculation step selects a direction along which nearby pixels having color information to be used to calculate said first term and said second term are set based upon results of a judgment made by said first similarity judgment step; and said interpolation value calculation step selects a direction along which nearby pixels having color information to be used to calculate said third term are set based upon results of a judgment made by said second similarity judgment step.

[0047]

[2] In the recording medium according to claim 22 having

recorded therein an interpolation processing program, said interpolation value calculation step calculates a first term containing local average information with regard to the first color component and curvature information with regard to a color component matching a color component at the interpolation target pixel, and a second term containing curvature information with regard to a color component other than the color component at the interpolation target pixel to calculate the interpolation value.

[0048]

[3] In the recording medium according to [1] having recorded therein an interpolation processing program: when image data are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel; said first similarity judgment step calculates similarity degrees manifested by the

interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees; said second similarity judgment step calculates similarity degrees manifested by the interpolation target pixel along two diagonal directions in which nearby pixels with color information corresponding to the third color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and said interpolation value calculation step selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second similarity judgment step when calculating said third term.

[0049]

[4] In the recording medium according to [3] having recorded therein an interpolation processing program, said

interpolation value calculation step calculates the third term based upon color information corresponding to the first color component if said second similarity judgment step judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the third term based upon color information corresponding to the third color component if said second similarity judgment step judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal direction.

[0050]

[5] In the recording medium according to claim 22 having recorded therein an interpolation processing program: when image data are provided in a colorimetric system constituted of first ~ third color components with the first color component achieving a higher spatial frequency than the second color component and the third color component, the first color component set in a checker-board pattern, the second color component and the third color component each set in a line sequence between pixels at which color information corresponding to the first color component is present and information corresponding to the second color component present at the interpolation target pixel; said first similarity judgment step calculates similarity degrees manifested by the

interpolation target pixel along two directions, i.e., a vertical direction and a horizontal direction, in which nearby pixels with color information corresponding to the first color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon a difference between said similarity degrees; said second similarity judgment step calculates similarity degrees manifested by the interpolation target pixel along two diagonal directions in which nearby pixels with color information corresponding to the third color component are connected to the interpolation target pixel and makes a judgment with regard to degrees of similarity manifested by the interpolation target pixel along the two diagonal directions based upon a difference between said similarity degrees; and said interpolation value calculation step selects color information corresponding to the first color component or color information corresponding to the third color component to be used in conformance to the degrees of similarity judged by said second similarity judgment step when calculating said second term.

[0051]

[6] In the recording medium according to [5] having recorded therein an interpolation processing program, said

interpolation value calculation step calculates the second term based upon color information corresponding to the first color component if said second similarity judgment step judges that roughly equal degrees of similarity manifest along the two diagonal directions and calculates the second based upon color information corresponding to the third color component if said second similarity judgment step judges that a higher degree of similarity manifests along one of the two diagonal directions compared to the other diagonal direction.

[0052]

[7] In the recording medium according to [3] or [5] having recorded therein an interpolation processing program: said first similarity judgment step judges that roughly equal degrees of similarity manifest along the vertical direction and the horizontal direction if a difference between the similarity degrees along the vertical direction and the horizontal direction is smaller than a specific threshold value; and said second similarity judgment step judges that roughly equal degrees of similarity manifest along the two diagonal directions if a difference between the similarity degrees along the two diagonal directions is smaller than a specific threshold value.

[0053]

[8] In the recording medium according to [3] or [5] having recorded therein an interpolation processing program: said first similarity judgment step calculates the similarity degrees along the vertical direction and the horizontal direction by using color information corresponding to a plurality of color components for a single interpolation target pixel; and said second similarity judgment step calculates the similarity degrees along the two diagonal directions by using color information corresponding to a plurality of color components for a single interpolation target pixel.

[0054]

[9] In the recording medium according to [8] having recorded therein an interpolation processing program, said second similarity judgment step calculates a similarity degree manifesting along each of the two diagonal directions through weighted addition of:

(1) a similarity degree component constituted of color information corresponding to the first color component alone;

(2) a similarity degree component constituted of color information corresponding to the second color component alone;

(3) a similarity degree component constituted of color information corresponding to the third color component

alone; and

(4) a similarity degree component constituted of color information corresponding to the second color component and the third color component.

[0055]

[10] In the recording medium according to [3] or [5] having recorded therein an interpolation processing program: said first similarity judgment step calculates similarity degrees along the vertical direction and the horizontal direction for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the vertical direction and the horizontal direction based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel; and said second similarity judgment step calculates similarity degrees along the two diagonal directions for each pixel and makes a judgment on similarity manifested by the interpolation target pixel along the two diagonal directions based upon differences in similarity degrees manifesting at nearby pixels as well as at the interpolation target pixel.

[0056]

[11] In the recording medium according to claim 23 having recorded therein an interpolation processing program said interpolation value calculation step uses color

information corresponding to a plurality of color components provided at the interpolation target pixel and at a plurality of pixels set along a predetermined direction relative to the interpolation target pixel to ascertain inclinations manifesting in color information corresponding to the individual color components along the direction and calculates said weighting coefficient in conformance to a correlation manifesting among the inclinations in the color information corresponding to the individual color components.

[0057]

[12] In the recording medium according to claim 24 or 25 having recorded therein an interpolation processing program, when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component, said hue value interpolation step calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels near the interpolation target pixel if the green color component is present but the red color component is missing at the interpolation target pixel and calculates a hue value for the interpolation target pixel by using a median of hue values containing the blue color component at pixels near

the interpolation target pixel if the green color component is present but the blue color component is missing at the interpolation target pixel.

[0058]

[13] In the recording medium according to claims 24 or 25 having recorded therein an interpolation processing program, when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component, said hue value interpolation step calculates a hue value for the interpolation target pixel by using a median of hue values containing the red color component at pixels set near the interpolation target pixel if the blue color component is present but the red color component is missing at the interpolation target pixel.

[0059]

[14] In the recording medium according to claims 24 or 25 having recorded therein an interpolation processing program, when the luminance component in the image data corresponds to a green color component and the color component in the image data corresponds to a red color component and a blue color component, said hue value interpolation step calculates a hue value for the interpolation target pixel by using a median of hue values

containing the blue color component at pixels set near the interpolation target pixel if the red color component is present but the blue color component is missing at the interpolation target pixel.

[0060]

[15] In the recording medium according to claim 24, claim 25, [12], [13] or [15] having recorded therein an interpolation processing program, with a color component missing at the interpolation target pixel present at only one pixel among four pixels set symmetrically along the vertical direction and the horizontal direction, said hue value interpolation step comprises: a first hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a plurality of diagonally adjacent pixels if the hue values of the plurality of diagonally adjacent pixels adjacent to the interpolation target pixel along diagonal directions have been calculated by said hue value calculation step; and a second hue value interpolation unit that calculates a hue value for the interpolation target pixel by using a median of hue values at a plurality of vertically and horizontally adjacent pixels if the hue values of the plurality of vertically and horizontally adjacent pixels adjacent to the interpolation target pixel in the vertical direction and the horizontal

direction have been calculated by said hue value calculation step or said first hue value interpolation unit.

[0061]

[Preferred Embodiment]

The following is a detailed explanation of the embodiments of the present invention, given in reference to the drawings. FIG. 1 is a functional block diagram of the electronic camera corresponding to the first through fourth embodiments.

It is to be noted that an electronic camera according to the first embodiment corresponds to an electronic camera comprising functions of interpolation processing executed by an interpolation processing apparatus according to any one of claims 1-12 and 15-20, an electronic camera according to the second embodiment corresponds to an electronic camera comprising functions of interpolation processing executed by an interpolation processing apparatus according to any one of claims 1-4 and 15-20, and an electronic camera according to the third embodiment or the fourth embodiment corresponds to an electronic camera comprising functions of interpolation processing executed by an interpolation processing apparatus according to any one of claims 13 and 14.

[0062]

In FIG. 1, an electronic camera 10 comprises a control unit 11, a photographic optical system 12, an image-capturing unit 13, an A/D conversion unit 14, an image processing unit 15 and a recording unit 16. The image processing unit 15 is provided with an interpolation processing unit (e.g., a one-chip microprocessor dedicated to interpolation processing). The image-capturing unit 13 is provided with an image-capturing sensor (not shown) constituted by arranging R, G and B color filters in a Bayer array.

[0063]

It is to be noted that while FIG. 1 shows only the interpolation processing unit 17 in the image processing unit 15 to simplify the illustration, a functional block that engages in other image processing such as gradation conversion processing may also be provided in the image processing unit 15.

In FIG. 1, the control unit 11 is connected to the image-capturing unit 13, the A/D conversion unit 14, the image processing unit 15 and the recording unit 16. In addition, an optical image obtained at the photographic optical system 12 is formed at the image-capturing sensor in the image-capturing unit 13. An output from the image-capturing unit 13 is quantized at the A/D conversion unit 14 and is provided to the image processing unit 15 as

image data. The image data provided to the image processing unit 15 undergo interpolation processing at the interpolation processing unit 17 and they are recorded via the recording unit 16..

[0064]

FIG. 2 shows the arrangements of the color components in the image data adopted in the first embodiment and the third embodiment, and FIG. 3shows the arrangements of the color components in the image data adopted in the second embodiment and the fourth embodiment. It is to be noted that in FIGS. 2A and 2B and in FIGS. 3A and 3B, the individual color components are indicated as R, G and B, with the positions of pixels at which the various color components are present indicated with i and j.

[0065]

With [i,j] indicating the coordinates of an interpolation target pixel to undergo the interpolation processing, FIG. 2 shows the arrangement of 7 X 7 pixels with the interpolation target pixel at the center, whereas FIG. 3 shows the arrangement of 5 X 5 pixels with the interpolation target pixel at the center. In addition, FIGS. 2(1) and 3(1) each show an arrangement of pixels among which a pixel with the red color component is to undergo the interpolation processing, and FIGS. 2(2) and 3(3) each show an arrangement of pixels among which a

pixel with the blue color component is to undergo the interpolation processing.

[0066]

In the various embodiments to be detailed later, the interpolation processing unit 17 first implements the interpolation processing to supplement the green color interpolation values for pixels at which the green color component is missing (hereafter referred to as "G interpolation processing") and then engages in interpolation processing through which red color interpolation values and blue color interpolation values are supplemented at pixels at which the red color component and the blue color component are missing (hereafter referred to as "RB interpolation processing"). However, since the interpolation processing implemented to supplement blue color interpolation values (hereafter referred to as "B interpolation processing") is implemented in a manner identical to the manner with which the interpolation processing for supplementing red color interpolation values (hereafter referred to as "R interpolation processing ") is implemented, its explanation is omitted.

[0067]

In addition, it is assumed that the pixel at coordinates [i,j] is the interpolation target pixel to

undergo the G interpolation processing, to simplify the subsequent explanation. Since the green color interpolation value can be calculated through the G interpolation processing in each of the embodiments explained below regardless of the color component (red or blue) at the interpolation target pixel, R and B in FIG. 2 and FIG. 3 are all replaced with Z with the color information at the interpolation target pixel expressed as Z[i,j] and color information at other pixels also expressed in a similar manner in the following explanation.

[0068]

(First Embodiment)

FIGS. 4 and 5 present a flowchart of the operation achieved in the interpolation processing unit 17 in the first embodiment, with FIG. 4 corresponding to the operation of the interpolation processing unit 17 during the G interpolation processing and FIG. 5 corresponding to the operation of the interpolation processing unit 17 during the R interpolation processing.

The explanation of the operation achieved in the first embodiment given below focuses on the operation of the interpolation processing unit 17 by referring to FIGS. 4 and 5.

[0069]

First, the interpolation processing unit 17

calculates a similarity degree Cv[i,j] along the vertical direction and a similarity degree Ch[i,j] along the horizontal direction for an interpolation target pixel at which the green component is missing (FIG. 4 S1).

Now, the details of the processing implemented to calculate the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] in the first embodiment are explained.

[0070]

The interpolation processing unit 17 first calculates a plurality of types of similarity degree components along the vertical direction and the horizontal direction defined through the following formulae 10 ~ 21.

G-G similarity degree component along vertical direction: $Cv1[i,j]=|G[i,j-1]-G[i,j+1]|$ … formula 10

G-G similarity degree component along horizontal direction: $Ch1[i,j]=|G[i-1,j]-G[i+1,j]|$ … formula 11

B-B (R-R) similarity degree component along vertical direction: $Cv2[i,j]=(|Z[i-1,j-1]-Z[i-1,j+1]|+|Z[i+1,j-1]-Z[i+1,j+1]|)/2$ … formula 12

B-B (R-R) similarity degree component along horizontal direction: $Ch2[i,j]=(|Z[i-1,j-1]-Z[i+1,j-1]|+|Z[i-1,j+1]-Z[i+1,j+1]|)/2$ … formula 13

R-R (B-B) similarity degree component along vertical direction: $Cv3[i,j]=(|Z[i,j-2]-Z[i,j]|+|Z[i,j+2]-$

$Z[i,j]|)/2$ … formula 14

R-R (B-B) similarity degree component along horizontal direction: $Ch3[i,j]=(|Z[i-2,j]-Z[i,j]|+|Z[i+2,j]-Z[i,j]|)/2$ … formula 15

G-R (G-B) similarity degree component along vertical direction: $Cv4[i,j]=(|G[i,j-1]-Z[i,j]|+|G[i,j+1]-Z[i,j]|)/2$ … formula 16

G-R (G-B) similarity degree component along horizontal direction: $Ch4[i,j]=(|G[i-1,j]-Z[i,j]|+|G[i+1,j]-Z[i,j]|)/2$ … formula 17

B-G (R-G) similarity degree component along vertical direction: $Cv5[i,j]=(|Z[i-1,j-1]-G[i-1,j]|+|Z[i-1,j+1]-G[i-1,j]|+|Z[i+1,j-1]-G[i+1,j]|+|Z[i+1,j+1]-G[i+1,j]|)/4$ … formula 18

B-G (R-G) similarity degree component along horizontal direction: $Ch5[i,j]=(|Z[i-1,j-1]-G[i,j-1]|+|Z[i-1,j+1]-G[i,j+1]|+|Z[i+1,j-1]-G[i,j-1]|+|Z[i+1,j+1]-G[i,j+1]|)/4$ … formula 19

luminance similarity degree component along vertical direction: $Cv6[i,j]=(|Y[i,j-1]-Y[i,j]|+|Y[i,j+1]-Y[i,j]|)/2$ … formula 20

luminance similarity degree component along horizontal direction: $Ch6[i,j]=(|Y[i-1,j]-Y[i,j]|+|Y[i+1,j]-Y[i,j]|)/2$ … formula 21

In formulae 20 and 21, $Y[i,j]$ represents a value

calculated through

$$Y[i,j]=(4\cdot A[i,j]+2\cdot(A[i,j-1]+A[i,j+1]+A[i-1,j]+A[i+1,j])+A[i-1,j-1]+A[i-1,j+1]+A[i+1,j-1]+A[i+1,j+1])/16 \quad \cdots \text{ formula 22}$$

, which is equivalent to the luminance value generated through filtering processing in which the color information corresponding to the color components at nearby pixels around the interpolation target pixel is averaged at a ratio of R:G:B = 1:2:1. It is to be noted that A[i,j] represents an arbitrary set of color information on the Bayer array which may assume a G value or a Z value depending upon the position at which the color information is provided.

[0071]

Next, the interpolation processing unit 17 performs weighted addition of the plurality of types of similarity degree components along each direction by using weighting coefficients a1, a2, a3, a4, a5 and a6, as expressed in the follow formulae 23 and 24.

$$Cv0[i,j]=(a1\cdot Cv1[i,j]+a2\cdot Cv2[i,j]+a3\cdot Cv3[i,j]+a4\cdot Cv4[i,j]+a5\cdot Cv5[i,j]+a6\cdot Cv6[i,j])/(a1+a2+a3+a4+a5+a6) \quad \ldots \text{ formula 23}$$

$$Ch0[i,j]=(a1\cdot Ch1[i,j]+a2\cdot Ch2[i,j]+a3\cdot Ch3[i,j]+a4\cdot Ch4[i,j]+a5\cdot Ch5[i,j]+a6\cdot Ch6[i,j])/(a1+a2+a3+a4+a5+a6) \quad \ldots \text{ formula 24}$$

It is to be noted that the ratio among the weighting coefficients a1, a2, a3, a4, a5 and a6 in formulae 23 and 24 may be, for instance, " a1: a2: a3: a4: a5: a6: = 2:1:1:4:4:12 ."

[0072]

In the first embodiment, the similarity degrees are calculated by calculating the similarity degree components along the vertical and horizontal directions and performing weighted addition of the similarity degree components for nearby pixels around the interpolation target pixel as well as for the interpolation target pixel.

The interpolation processing unit 17 performs weighted addition of the results obtained by implementing weighted addition of the similarity degree components at the interpolation target pixel and the nearby pixels (Cv0[i,j], Cv0[i-1,j-1], Cv0[i-1,j+1], Cv0[i+1,j-1], Cv0[i+1,j+1] and the like), through either (method 1) or (method 2) detailed below, to obtain a similarity degree Cv[i,j] along the vertical direction and a similarity degree Ch[i,j] along the horizontal direction manifesting by the interpolation target pixel.

[0073]

(method 1)

$$Cv[i,j]=(4\cdot Cv0[i,j]+Cv0[i-1,j-1]+Cv0[i-1,j+1]+Cv0[i+1,j-1]+Cv0[i+1,j+1])/8 \quad \dots \text{formula } 25$$

Ch[i,j]=(4·Ch0[i,j]+Ch0[i-1,j-1]+Ch0[i-1,j+1]
+Ch0[i+1,j-1]+Ch0[i+1,j+1])/8 … formula 26

(method 2)

Cv[i,j]=(4·Cv0[i,j]
+2·(Cv0[i-1,j-1]+Cv0[i+1,j-1]+Cv0[i-1,j+1]+Cv0[i+1,j+1])
+Cv0[i,j-2]+Cv0[i,j+2]+Cv0[i-2,j]+Cv0[i+2,j])/16
… formula 27

Ch[i,j]=(4·Ch0[i,j]
+2·(Ch0[i-1,j-1]+Ch0[i+1,j-1]+Ch0[i-1,j+1]+Ch0[i+1,j+1])
+Ch0[i,j-2]+Ch0[i,j+2]+Ch0[i-2,j]+Ch0[i+2,j])/16
… formula 28

It is to be noted that while (method 1) corresponds to that weighted addition of the similarity degree components at the interpolation target pixel and the nearby pixels is implemented as illustrated in FIG. 6(1), (method 2) corresponds to that weighted addition of the similarity degree components at the interpolation target pixel and the nearby pixels is implemented as illustrated in FIG. 6(2).

[0074]

The similarity degree components each calculated by using color information corresponding to the same color component such as the G-G similarity degree components, B-B (R-R) similarity degree component and the R-R (B-B) similarity degree components (hereafter referred to as

"same-color similarity degree components") have been confirmed through testing to be suitable for use in the evaluation of similarity manifesting in an image with a low spatial frequency and a large colored area. The similarity degree components each calculated by using color information corresponding to different color components such as the G-R (G-B) similarity degree components and B-G (R-G) similarity degree components (hereafter referred to as "different-color similarity degree components") have been confirmed through testing to be suitable for use in the evaluation of similarity manifesting in an image with a high spatial frequency and a large achromatic image area. In addition, the luminance similarity degree components have been confirmed through testing to be suitable for use in the evaluation of similarity manifesting in an image containing both a colored area and an image area with a fairly high spatial frequency.

[0075]

In other words, the evaluation of similarity manifesting in various types of images can be achieved with a high degree of accuracy by using similarity degrees obtained through weighted addition of same-color similarity degree components, different-color similarity degree components and luminance similarity degree

components.

In addition, the functions of the three types of similarity degree components calculated as the same-color similarity degree components (the G-G similarity degree components, the B-B (R-R) similarity degree components and the R-R (B-B) similarity degree components) in the similarity evaluation can be complemented by one another and the functions of the two types of similarity degrees components calculated as the different-color similarity degree components (the G-R (G-B) similarity degree components and the B-G (R-G) similarity degree components) in the similarity evaluation, too, can be complemented by each other .

[0076]

Furthermore, in the first embodiment, the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] are calculated through weighted addition of the results of weighted addition of similarity degree components at the interpolation target pixel and the results of weighted addition of similarity degree components at nearby pixels. Thus, the continuity between the color information at the interpolation target pixel and the color information at the pixels located near the interpolation target pixel is readily reflected in the vertical similarity degree Cv[i,j] and the horizontal

similarity degree Ch[i,j].

[0077]

In particular , the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] calculated through (method 2) reflect color information corresponding to the color components at pixels over a wide range and thus, are effective in the similarity evaluation of an image manifesting a pronounced magnification chromatic aberration.

It is to be noted that the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] in the first embodiment indicate more marked similarity as their values become smaller.

[0078]

After the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] are calculated as described above, the interpolation processing unit 17 compares the similarity along the vertical direction and the similarity along the horizontal direction manifesting at the interpolation target pixel (hereafter referred to as the "vertical/horizontal similarity") based upon the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] (FIG. 4 S2). Then, it sets one of the following values for an index HV[i,j] which indicates the vertical/horizontal similarity based upon

the results of the comparison.

[0079]

For instance, if |Cv[i,j] - Ch[i,j]| > T1 and Cv[i,j] < Ch[i,j] are true with regard to a given threshold value T1, the interpolation processing unit 17 judges that a more marked similarity is manifested along the vertical direction than along the horizontal direction and sets 1 for the index HV[i,j] (FIG. 4 S3), if; |Cv[i,j] - Ch[i,j]| > T1 and Cv[i,j] > Ch[i,j] are true, the interpolation processing unit 17 judges that a more marked similarity is manifested along the horizontal direction than along the vertical direction and sets -1 for the index HV[i,j] (FIG. 4 S4) and if; |Cv[i,j] - Ch[i,j]| ≦ T1 is true, the interpolation processing unit 17 judges that the degree of similarity manifested along the horizontal direction and along the vertical direction are essentially the same and sets 0 for the index HV[i,j] (FIG. 4 S5).

[0080]

It is to be noted that the threshold value T1 is used to prevent an erroneous judgment that the similarity along either direction is more marked from being made due to noise when the difference between the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j] is very little. Accordingly, by setting a high value for the threshold value T1 when processing a color

image with a great deal of noise, an improvement in the accuracy of the vertical/horizontal similarity judgment is achieved.

Next, the interpolation processing unit 17 calculates a similarity degree C45[i,j] along the diagonal 45° direction and a similarity degree C135[i,j] along the diagonal 135° degree direction for the interpolation target pixel (FIG. 4 S6).

[0081]

Now, details of the processing implemented in the first embodiment to calculate the diagonal 45° similarity degree C45[i,j] and the diagonal 135° similarity degree C135[i,j] are explained.

First, the interpolation processing unit 17 calculates a plurality of types of similarity degree components along the diagonal 45° direction and the diagonal 135° direction as defined in the following formulae 29 ~ 36;

G-G similarity degree component along the diagonal 45° direction:

$$C45\_1[i,j]=(|G[i,j-1]-G[i-1,j]|+|G[i+1,j]-G[i,j+1]|)/2$$

… formula 29

G-G similarity degree component along the diagonal 135° direction:

$$C135\_1[i,j]=(|G[i,j-1]-G[i+1,j]|+|G[i-1,j]-G[i,j+1]|)/2$$

… formula 30

B-B (R-R) similarity degree component along the diagonal 45° direction:

C45_2[i,j]=|Z[i+1,j-1]-Z[i-1,j+1]| … formula 31

B-B (R-R) similarity degree component along the diagonal 135° direction:

C135_2[i,j]=|Z[i-1,j-1]-Z[i+1,j+1]| … formula 32

R-R (B-B) similarity degree component along the diagonal 45° direction:

C45_3[i,j]=(|Z[i+2,j-2]-Z[i,j]|+|Z[i-2,j+2]-Z[i,j]|)/2

… formula 33

R-R (B-B) similarity degree component along the diagonal 135° direction:

C135_3[i,j]=(|Z[i-2,j-2]-Z[i,j]|+|Z[i+2,j+2]-Z[i,j]|)/2

… formula 34;

B-R (R-B) similarity degree component along the diagonal 45° direction:

C45_4[i,j]=(|Z[i+1,j-1]-Z[i,j]|+|Z[i-1,j+1]-Z[i,j]|)/2

… formula 35

B-R (R-B) similarity degree component along the diagonal 135° direction:

C135_4[i,j]=(|Z[i-1,j-1]-Z[i,j]|+|Z[i+1,j+1]-Z[i,j]|)/2

… formula 36;

Next, the interpolation processing unit 17 performs weighted addition of the plurality of types of similarity

degree components performed along each of the two directions by using weighting coefficients b1, b2, b3 and b4 , as expressed in the following formulae 37 and 38.

[0082]

$$C45\_0[i,j]=(b1\cdot C45\_1[i,j]+b2\cdot C45\_2[i,j]+b3\cdot C45\_3[i,j]+b4\cdot C45\_4[i,j])/(b1+b2+b3+b4) \quad \ldots \text{ formula 37}$$

$$C135\_0[i,j]=(b1\cdot C135\_1[i,j]+b2\cdot C135\_2[i,j]+b3\cdot C135\_3[i,j]+b4\cdot C135\_4[i,j])/(b1+b2+b3+b4) \quad \ldots \text{ formula 38}$$

It is to be noted that the ratio of the weighting coefficients b1, b2, b3 and b4 in formulae 37 and 38 may be, for instance, "b1:b2:b3:b4: = 2:1:1:2."

[0083]

In the first embodiment, a further improvement is achieved in the accuracy with which the similarity degrees are calculated by calculating the similarity degree components along the diagonal 45° direction and the diagonal 135° direction and performing weighted addition of the similarity degree components for nearby pixels around the interpolation target pixel as well as for the interpolation target pixel.

Namely, the interpolation processing unit 17 performs weighted addition of the results obtained by implementing weighted addition of the similarity degree components at the interpolation target pixel and the nearby pixels (C45_0[i,j], C45_0[i-1,j-1], C45_0[i-1,j+1], C45_0[i+1,j-

1], C45_0[i+1,j+1] and the like) through either (method 1) or (method 2) detailed below, to obtain a similarity degree Cv[i,j] along the diagonal 45° direction and a similarity degree Ch[i,j] along the diagonal 135° direction manifesting by the interpolation target pixel (equivalent to implementing weighted addition of similarity degree components at the interpolation target pixel and the nearby pixels as illustrated in FIGS. 6(1) and 6B).

[0084]

(method 1)

C45[i,j]=(4·C45_0[i,j]+C45_0[i-1,j-1]+C45_0[i+1,j-1]
+C45_0[i-1,j+1]+C45_0[i+1,j+1])/8 … formula 39

C135[i,j]=(4·C135_0[i,j]+C135_0[i-1,j-1]+C135_0[i+1,j-1]
+C135_0[i-1,j+1]+C135_0[i+1,j+1])/8 … formula 40

(method 2)

C45[i,j]=(4·C45_0[i,j]+2·(C45_0[i-1,j-1]+C45_0[i+1,j-1]
+C45_0[i-1,j+1]+C45_0[i+1,j+1])+C45_0[i,j-2]
+C45_0[i,j+2]+C45_0[i-2,j]+C45_0[i+2,j])/16
… formula 41

C135[i,j]=(4·C135_0[i,j]+2·(C135_0[i-1,j-1]+C135_0[i+1,j-1]
+C135_0[i-1,j+1]+C135_0[i+1,j+1])+C135_0[i,j-2]
+C135_0[i,j+2]+C135_0[i-2,j]+C135_0[i+2,j])/16
… formula 42

It is to be noted that the weighted addition of the

plurality of similarity degree components and the consideration of the evaluation of similarity degrees at the nearby pixels with regard to the diagonal 45° similarity degree C45[i,j] and the diagonal 135° similarity degree C135[i,j] thus calculated achieves the same function as that with regard to the vertical similarity degree Cv[i,j] and the horizontal similarity degree Ch[i,j]. In addition, the diagonal 45° similarity degree C45[i,j] and the diagonal 135° similarity degree C135[i,j] in the first embodiment indicate more marked similarity as their values become smaller.

[0085]

After the diagonal 45° similarity degree C45[i,j] and the diagonal 135° similarity degree C135[i,j] are calculated, the interpolation processing unit 17 compares the similarity along the diagonal 45° direction and the similarity along the diagonal 135° direction manifesting at the interpolation target pixel (hereafter referred to as the "diagonal similarity") based upon the diagonal 45° similarity degree C45[i,j] and the diagonal 135° similarity degree C135[i,j] (FIG. 4 S7). Then, it sets one of the following values for an index DN[i,j] which indicates the diagonal similarity based upon the results of the comparison.

[0086]

For instance, if; $|C45[i,j] - C135[i,j]| > T2$ and $C45[i,j] < C135[i,j]$ are true with regard to a given threshold value T2, the interpolation processing unit 17 judges that a more marked similarity is manifested along the diagonal 45° direction than along the diagonal 135° direction and sets 1 for the index DN[i,j] (FIG. 4 S8), if; $|C45[i,j] - C135[i,j]| > T2$ and $C45[i,j] > C135[i,j]$ are true, the interpolation processing unit 17 judges that a more marked similarity is manifested along the diagonal 135° direction than along the diagonal 45° direction and sets -1 for the index DN[i,j] (FIG. 4 S9) and if; $|C45[i,j] - C135[i,j]| \leqq T2$ is true, the interpolation processing unit 17 judges that the degree of similarity manifesting along the diagonal 45° direction and along the diagonal 135° direction are essentially the same and sets 0 for the index DN[i,j] (FIG. 4 S10).

[0087]

It is to be noted that the threshold value T2 is used to prevent an erroneous judgment that the similarity along either direction is more marked from being made due to noise.

Next, the interpolation processing unit 17 ascertains the specific values of the index HV[i,j] indicating the vertical/horizontal similarity and the index DN[i,j] indicating the diagonal similarity (FIG. 4 S11) and

classifies the class of the similarity manifesting at the interpolation target pixel as one of the following; case 1 ~ case 9.

[0088]

case 1: (HV[i,j], DN[i,j]) = (1, 1): marked similarity manifesting along the vertical direction and the diagonal 45° direction

case 2: (HV[i,j], DN[i,j]) = (1, 0): marked similarity manifesting along the vertical direction

case 3: (HV[i,j], DN[i,j]) = (1, -1): marked similarity manifesting along the vertical direction and the diagonal 135° direction

case 4: (HV[i,j], DN[i,j]) = (0, 1): marked similarity manifesting along the diagonal 45° direction

case 5: (HV[i,j], DN[i,j]) = (0, 0): marked similarity manifesting along all the directions or little similarity manifesting along all the directions

[0089]

case 6: (HV[i,j], DN[i,j]) = (0, -1): marked similarity manifesting along the diagonal 135° direction

case 7: (HV[i,j], DN[i,j]) = (-1, 1): marked similarity manifesting along the horizontal direction and the diagonal 45° direction

case 8: (HV[i,j], DN[i,j]) = (-1, 0): marked similarity manifesting along the horizontal direction

case 9: (HV[i,j], DN[i,j]) = (-1, -1): marked similarity manifesting along the horizontal direction and the diagonal 135° direction.

FIG. 7 illustrates the directions along which marked similarity manifests, as indicated by the values of HV[i,j], DN[i,j]

[0090]

In FIG. 7, there is no directional indication that corresponds to "case 5: (HV[i,j], DN[i,j]) , = (0, 0)." A marked similarity manifesting along all the directions or only a slight similarity manifesting along all the directions as in case 5 means that the interpolation target pixel is contained within a flat area or is an isolated point (an image area manifesting a lower degree of similarity to nearby pixels and having a high spatial frequency).

Next, the interpolation processing unit 17 calculates the green color interpolation value G[i,j] as indicated below based upon the results of the judgment explained above.

[0091]

In case 1, G[i,j] = Gv45[i,j] : FIG. 4 S12

In case 2, G[i,j] = Gv[i,j] : FIG. 4 S13

In case 3, G[i,j] = Gv135[i,j] : FIG. 4 S14

In case 4, G[i,j] = (Gv45[i,j] + Gh45[i,j]) /2 : FIG.

4 S15

In case 5, G[i,j] = (Gv[i,j] + Gh[i,j]) /2 : FIG. 4 S16

In case 6, G[i,j] = (Gv135[i,j] + Gh135[i,j]) /2 : FIG. 4 S17

In case 7, G[i,j] = Gh45[i,j] : FIG. 4 S18

In case 8, G[i,j] = Gh[i,j] : FIG. 4 S19

In case 9, G[i,j] = Gh135[i,j] : FIG. 4 S20, with

Gv[i,j]=(G[i,j-1]+G[i,j+1])/2
+(2·Z[i,j]-Z[i,j-2]-Z[i,j+2])/8
+(2·G[i-1,j]-G[i-1,j-2]-G[i-1,j+2]
+2·G[i+1,j]-G[i+1,j-2]-G[i+1,j+2])/16 … formula 43

Gv45[i,j]=(G[i,j-1]+G[i,j+1])/2
+(2·Z[i,j]-Z[i,j-2]-Z[i,j+2])/8
+(2·Z[i-1,j+1]-Z[i-1,j-1]-Z[i-1,j+3]
+2·Z[i+1,j-1]-Z[i+1,j-3]-Z[i+1,j+1])/16 … formula 44

Gv135[i,j]=(G[i,j-1]+G[i,j+1])/2
+(2·Z[i,j]-Z[i,j-2]-Z[i,j+2])/8
+(2·Z[i-1,j-1]-Z[i-1,j-3]-Z[i-1,j+1]
+2·Z[i+1,j+1]-Z[i+1,j-1]-Z[i+1,j+3])/16 … formula 45

Gh[i,j]=(G[i-1,j]+G[i+1,j])/2
+(2·Z[i,j]-Z[i-2,j]-Z[i+2,j])/8
+(2·G[i,j-1]-G[i-2,j-1]-G[i+2,j-1]
+2·G[i,j+1]-G[i-2,j+1]-G[i+2,j+1])/16 … formula 46

Gh45[i,j]=(G[i-1,j]+G[i+1,j])/2

$+(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/8$

$+(2\cdot Z[i+1,j-1]-Z[i-1,j-1]-Z[i+3,j-1]$

$+2\cdot Z[i-1,j+1]-Z[i-3,j+1]-Z[i+1,j+1])/16$ … formula 47

$Gh135[i,j]=(G[i-1,j]+G[i+1,j])/2$

$+(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/8$

$+(2\cdot Z[i-1,j-1]-Z[i-3,j-1]-Z[i+1,j-1]$

$+2\cdot Z[i+1,j+1]-Z[i-1,j+1]-Z[i+3,j+1])/16$… formula 48

[0092]

FIG. 8 shows the positions of the color information used to calculate the green color interpolation value G[i,j]. In FIG. 8, the color information at the circled pixels is used as a contributing factor in the curvature information that constitutes the green color interpolation value G[i,j].

It is to be noted that Gv[i,j]and Gh[i,j] may be calculated with following formulas to simplify the calculation prodcessing.

[0093]

$Gv[i,j]=(G[i,j-1]+G[i,j+1])/2$

$+(2\cdot Z[i,j]-Z[i,j-2]-Z[i,j+2])/4$ ··· formula 44'

$Gh[i,j]=(G[i-1,j]+G[i+1,j])/2$

$+(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/4$ ··· formula 46'

In each of formulae 43 ~ 48, the first term constitutes the "average information of the green color component" and corresponds to the primary terms in

formulae 1 and 2. The second term represents the "curvature information based upon a color component matching a color component at the interpolation target pixel" and the third term represents the "curvature information based upon a color component other than the color component at the interpolation target pixel."

[0094]

In other words, in the first embodiment, the average information of the green color component is corrected by using the "curvature information based upon a color component matching the color component at the interpolation target pixel" and the "curvature information based upon a color component other than the color component at the interpolation target pixel."

For instance, when marked similarity manifests along the diagonal directions and the green color interpolation value is calculated by using Gv45[i,j], Gv135[i,j], Gh45[i,j] and Gh135[i,j] (case 1, case 3, case 4, case 6, case 7 or case 9), the average information of the green color component (the primary term) is corrected by using the local information based upon the red color component and the curvature information based upon the blue color component at phases that are opposite from each other.

[0095]

Thus, even when the color information corresponding

to the red color component and the color information corresponding to the blue color component are offset relative to the color information corresponding to the green color component due to magnification chromatic aberration, as illustrated in FIG. 9(1) (equivalent to a drawing achieved by superimposing FIG. 16(2) on FIG. 16(3)), the primary term is corrected in correspondence to the average quantity of change in the color information corresponding to the red color component and the color information corresponding to the blue color component, as in FIG. 9(2). As a result, by adopting the first embodiment, the primary term can be corrected for a desired pixel even if there is magnification chromatic aberration at the photographic optical system 12, with the overshoot and the undershoot occurring as a result of the G interpolation processing disclosed in USP No. 5,629,734 canceled out by each other. Consequently, the occurrence of color artifacts attributable to over correction can be reduced in the first embodiment.

[0096]

It is to be noted that while an overshoot may also occur when correcting a primary term constituted of color information corresponding to the blue color component as well as when correcting a primary term constituted of color information corresponding to the red color component,

overshoot values corresponding to the individual color components are averaged in the first embodiment and thus, the average value does not exceed an overshoot value resulting from the G interpolation processing disclosed in USP No. 5,629,734. In addition, even if an undershoot occurs when correcting a primary term constituted of color information corresponding to the blue color component or correcting a primary term constituted of color information corresponding to the red color component, the undershoot value in the first embodiment never exceeds the undershoot value resulting from the G interpolation processing disclosed in USP No. 5,629,734.

[0097]

In the first embodiment, the image data to undergo the G interpolation processing are arranged in a Bayer array as shown in FIG. 2, with the color information corresponding to the red color component and the color information corresponding to the blue color component positioned diagonally to each other. Thus, if color information corresponding to the blue color component is provided at the interpolation target pixel, for instance, the local curvature information based upon the red color component to be used to correct the primary term is calculated by using color information corresponding to the red color component at pixels positioned along a diagonal

direction along which marked similarity to the interpolation target pixel manifests. In addition, the green color interpolation value is calculated by using the color information at pixels set along a diagonal direction distanced from the interpolation target pixel such as Z[i-1,j+3] and Z[i+1,j-3] in formula 44, Z[i-1,j-3] and Z[i+1,j+3] in formula 45, Z[i+3,j-1] and Z[i-3,j+1] in formula 47 and Z[i-3,j-1] and Z[i+3,j+1] in formula 48.

[0098]

As a result, in the G interpolation processing in the first embodiment which requires a highly accurate judgment on the diagonal similarity, the interpolation processing unit 17 achieves a high degree of accuracy in the judgement of the diagonal similarity by using a plurality of sets of color information when calculating a plurality of types of similarity degree components along the diagonal 45° direction and the diagonal 135° direction.

In other words, the accuracy of the interpolation processing is improved through a highly accurate judgment on the diagonal similarity in the first embodiment.

[0099]

In addition, if marked similarity manifests along the vertical direction or the horizontal direction and thus the green interpolation value is calculated using Gv[i,j] or Gh[i,j] (case 2 or case 8), curvature information based

upon the green color component is used as the "curvature information based upon a color component other than the color component at the interpolation target pixel" and the average information of the green color component is corrected by using curvature information based upon the red color component or the blue color component and curvature information based upon the green color component.

[0100]

Under normal circumstances, the effect of magnification chromatic aberration often manifests as a large offset between the red color component and the green color component and a slight offset between the blue color component and the green color component. Thus, if color information corresponding to the red color component is provided at the interpolation target pixel, the curvature information based upon the green color component can be used as a component at a phase opposite from the phase of the curvature information based upon the red color component to reduce the occurrence of color artifacts resulting from over correction. In addition, since the effect of a magnification chromatic aberration is less evident if color information corresponding to the blue color component is present at the interpolation target pixel, color artifacts occur less readily as a result of over correction.

[0101]

In the following explanation of the RB interpolation processing operation, the RB interpolation processing implemented in the prior art is first described and then the R interpolation processing in FIG. 5 in the RB interpolation processing implemented in the first embodiment is explained (an explanation of the B interpolation processing is omitted).

A known example of the RB interpolation processing in the prior art is linear interpolation processing implemented in a color difference space in which after calculating color differences at all the pixels (values each obtained by subtracting the value indicated by color information corresponding to the green color component from the value indicated by color information corresponding to the red color component (or the blue color component)), one of the three different types of processing (1) ~ (3) described below is implemented on each interpolation target pixel to calculate the interpolation value.

[0102]

(1) If a color component missing at the interpolation target pixel is present at the two pixels adjacent to the interpolation target pixel along the vertical direction, the interpolation target value is calculated as a value

achieved by adding the color information corresponding to the green color component at the interpolation target pixel to the average of the color differences at the two pixels.

(2) If a color component missing at the interpolation target pixel is present at the two pixels adjacent to the interpolation target pixel along the horizontal direction, the interpolation target value is calculated as a value achieved by adding the value indicated by the color information corresponding to the green color component at the interpolation target pixel to the average of the color differences at the two pixels.

[0103]

(3) If a color component missing at the interpolation target pixel is present at the four pixels adjacent to the interpolation target pixel along the diagonal directions, the interpolation target value is calculated as a value achieved by adding the value indicated by the color information corresponding to the green color component at the interpolation target pixel to the average of the color differences at the four pixels.

In addition, interpolation processing that incorporates nonlinear median processing, which is more effective in preventing color artifacts compared to linear processing in a color difference space is also implemented

in the prior art.

[0104]

In the art disclosed in USP No. 5,799,113, in which video signals provided in one of the following colorimetric systems, RGB, YUV and YCbCr, undergo culled compression at a resolution of 1/4 to reduce the transmission volume, nonlinear median processing is implemented to restore the video signals to the original resolution by interpolating 3-component data at the culled pixels which have been lost. For instance, if the video signals are provided in the YCbCr colorimetric system, the interpolation values for the luminance component Y and the interpolation values corresponding to the color components Cb and Cr at the culled pixels marked O, △ and X in FIGS. 10(1) ~ 10C are calculated through identical arithmetic processing. It is to be noted that in order to retain the structure at an edge, the pixel marked X alone is interpolated by using the median value (median) of the values at four nearby pixels, the pixels marked O are each interpolated by using the average of the values at the pixels adjacent along the horizontal direction and the pixels marked △ are each interpolated by using the average of the values at the pixels adjacent along the vertical direction.

[0105]

However, while the interpolation processing implemented as described above is effective in restoring the image quality in a dynamic image, it is not suited for processing a still image that requires high definition. Namely, the art disclosed in USP No. 5,799,113, in which the luminance component Y and the color components Cr and Cb are handled in exactly the same way, achieves only a very low degree of accuracy with regard to the interpolation values for the luminance component Y which determines the resolution. In addition, since the luminance component Y is interpolated by using the median, the likelihood of the image structure becoming lost is high. Furthermore, there is a concern that color artifacts may spread when the data are converted to the RGB colorimetric system.

[0106]

In an electronic camera which employs an image-capturing sensor constituted by arranging R, G and B color filters in a Bayer array to generate a still image, the interpolation processing on the green color component which is equivalent to the luminance component with a high spatial frequency (G interpolation processing) can be implemented with a very high degree of accuracy by using similarity manifesting between the interpolation target pixel and nearby pixels and calculating the interpolation

value using a plurality of color components, as explained earlier. In such an electronic camera, after implementing high-definition interpolation processing on the green color component, which most faithfully reflects the high-frequency information in the image data, the interpolation processing on the red color component and the blue color component is achieved through linear interpolation in color difference spaces relative to the green color component to reduce color artifacts by reflecting the high-frequency information in the image data in the red color component and the blue color component.

[0107]

For instance, if the sets of color information at individual pixels are arranged one-dimensionally in the order of (R1, G2, R3), the red color interpolation value is calculated through;

$R2=(R1+R3)/2+(2\cdot G2-G1-G3)/2$ … formula 49. In the formula, G2 represents color information corresponding to the green color component in the original image and G1 and G3 each represent a green color interpolation value obtained through the G interpolation processing.

[0108]

However, this RB interpolation processing poses a problem in that the color artifact is allowed to remain in the vicinity of an isolated point (an image area

manifesting only slight similarity to nearby pixels and having a high spatial frequency). In the prior art, this type of color artifact is often eliminated in post processing, in which a and b hue planes obtained by converting the image data to the Lab colorimetric system individually undergo median filtering after the G interpolation processing and the RB interpolation processing are implemented.

[0109]

Since a 3 x 3 (= 9 points) filter size achieves hardly any effect, the filter size must be set over a large range of 5 x 5 (= 25 points) when applying such a median filter.

In other words, in the electronic camera described above, extremely heavy processing must be implemented since both the RB interpolation processing in the prior art and the median processing must be performed in the interpolation processing on the red color component and the blue color component in a still image and also the filter size must be set over a wide range for the median processing. Furthermore, the risk of the fine structure in a colored area (hereafter referred to as a "color structure") being lost is higher when the filter size in the median processing is increased.

[0110]

Accordingly, in the first embodiment, RB interpolation processing through which red color and blue color interpolation values can be calculated quickly with a high degree of accuracy without allowing any color artifacts to remain in the vicinity of an isolated point or losing the color structure is proposed. It is to be noted that the following is an explanation of the only R interpolation processing in the RB interpolation processing, given in reference to FIG. 5.

First, the interpolation processing unit 17 calculates a color difference that contains the red color component for each pixel at which color information corresponding to the red color component is present by subtracting the green color interpolation value (the value obtained through the G interpolation processing explained earlier) from the value indicated by the color information corresponding to the red color component (FIG. 5 S1).

[0111]

For instance, the interpolation processing unit 17 calculates a color difference Cr[i,j] containing the red color component at a pixel at given coordinates [i,j] with color information corresponding to the red color component as; Cr[i,j]=R[i,j]-G[i,j] … formula 50.

It is to be noted that in the first embodiment, when

the color differences containing the red color component have been calculated as described above, the color differences containing the red color component are set so as to surround pixels at which color information corresponding to the red color component is missing and color information corresponding to the blue color component is present from the four diagonal directions.

[0112]

The interpolation processing unit 17 interpolates the color difference containing the red color component for each of the pixels surrounded by color differences containing the red color component from the four diagonal directions (each pixel at which color information corresponding to the red color component is missing and color information corresponding to the blue color component is present in the first embodiment) by using the median of the color differences containing the red color component at the pixels set diagonally to the target pixel (FIG. 5 S2).

Namely, in the first embodiment, the interpolation processing unit 17 calculates the color difference Cr[m,n] at the pixel at given coordinates [m,n] surrounded by color differences containing the red color component from the four diagonal directions as shown in FIG. 11(1) through;

Cr[m,n]=median{Cr[m-1,n-1],Cr[m+1,n-1],
Cr[m-1,n+1],Cr[m+1,n+1]} … formula 51.

In the formula, median{} represents a function through which the median of a plurality of elements is calculated and, if there are an even number of elements, it takes the average of the two middle elements.

[0113]

In the first embodiment, when the color differences containing the red color component have been calculated through formulae 50 and 51, the color differences containing the red color component are set so as to surround pixels at which color information corresponding to the red color component and color information corresponding to the blue color component are both missing from the four directions; i.e., from above, from below and from the left and the right.

The interpolation processing unit 17 interpolates the color difference containing the red color component for each of the pixels surrounded by color differences containing the red color component from the four directions; i.e., from above, from below and from the left and the right (each pixel at which color information corresponding to the red color component and color information corresponding to the blue color component are both missing in the first embodiment) by using the median

of the color differences containing the red color component at the pixels set above, below and to the left and the right of the pixel (FIG. 5 S3).

[0114]

Namely, in the first embodiment, the interpolation processing unit 17 calculates the color difference Cr[m,n] at the pixel at given coordinates [m,n] surrounded by color differences containing the red color component from the four directions; i.e., from above, from below and from the left and the right as shown in FIG. 11B through;

Cr[m,n]=median{Cr[m,n-1],Cr[m-1,n],
Cr[m+1,n],Cr[m,n+1]} … formula 52

[0115]

Next, the interpolation processing unit 17 converts the color difference containing the red color component calculated through formula 51 or formula 52 for each pixel at which color information corresponding to the red color component is missing to a red color interpolation value by using color information corresponding to the green color component (or the green color interpolation value) (FIG. 5 S4).

Namely, the interpolation processing unit 17 calculates the red color interpolation value R[m,n] for the pixel at given coordinates [m,n] through;

R[m,n]=Cr[m,n]+G[m,n] … formula 53.

[0116]

The median processing described above is implemented on the color differences representing the hue alone and is not implemented on the luminance component. In addition, when the pixel marked O in FIG. 12(1) is the interpolation target pixel in the R interpolation processing, the color differences containing the red color component at the pixels marked X are calculated by using the color differences Cr over a 3 x 5 range, and thus, the color difference containing the red color component at the pixel marked O represents a value which is close to the results of median processing implemented by weighting the color differences Cr within the 3 x 5 range. When the pixel marked △ in FIG. 12(2) is the interpolation target pixel, on the other hand, the color differences containing the red color component at the pixels marked X are calculated by using the color differences Cr over a 5 x 3 range, and thus, the color difference containing the red color component at the pixel marked △ represents a value which is close to the results of median processing implemented by weighting the color differences Cr within the 5 x 3 range.

[0117]

In other words, in the first embodiment, advantages substantially similar to those achieved through median

processing implemented over a wide range are achieved while keeping down the filter size. As a result, by adopting the first embodiment, the occurrence of color artifacts around an isolated point is reduced without destroying the color structure. Thus, a great improvement is achieved in the color artifact reduction effect over the art disclosed in USP No. 5,799,113.

[0118]

In addition, since the color differences at only four points are each used in the median processing in FIG. 5 S2 and FIG. 5 S3 in the first embodiment, good processing efficiency is achieved and extremely fast median processing is enabled.

It is to be noted that while the RB interpolation processing is implemented after the G interpolation processing in the first embodiment, RB interpolation processing similar to that in the embodiment can be implemented without having to perform G interpolation processing on image data provided in the YCbCr colorimetric system with Y, Cb and Cr culled at a ratio of 4:1:1 since the luminance component Y is left intact in the image data.

[0119]

(Second Embodiment)

The following is an explanation of the operation

achieved in the second embodiment.

It is to be noted that since the RB interpolation processing in the second embodiment is implemented as in the first embodiment, its explanation is omitted. However, in the second embodiment, color differences containing the red color component are interpolated for some of the pixels at which color information corresponding to the green color component is present (equivalent to the pixels provided with G color filters) through formula 51 presented earlier, and color differences containing the red color component are interpolated for the remaining pixels at which color information corresponding to the green color component is present and for the pixels at which color information corresponding to the blue color component is present through formula 52.

[0120]

The following is an explanation of the G interpolation processing.

Since the closest pixels at which the green color component (the closest green color component) is present are located along the horizontal direction relative to the pixel to undergo the G interpolation processing as shown in FIG. 3 in the second embodiment, it is not necessary to calculate the similarity degrees or to judge the direction along which similarity manifests as required in the first

embodiment during the G interpolation processing. However, the calculation of similarity degrees and judgment with regard to the direction along which similarity manifests may be performed along the diagonal 45° direction and the diagonal 135° direction in which the second closest pixels with green color component (the second closest green color component) are present.

[0121]

In the second embodiment, the interpolation processing unit 17 calculates the green color interpolation value G[i,j] through the following formula 54 based upon the image data arranged as shown in FIG. 3.

$$
\begin{aligned}
G[i,j]=&(G[i-1,j]+G[i+1,j])/2\\
&+(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/8\\
&+(2\cdot Z[i,j-1]-Z[i-2,j-1]-Z[i+2,j-1]\\
&+2\cdot Z[i,j+1]-Z[i-2,j+1]-Z[i+2,j+1])/16 \quad \ldots \quad \text{formula 54}
\end{aligned}
$$

In formula 54, the first term represents the "average information of the green color component", which is equivalent to the primary terms in formula 1 and formula 2. In addition, while the second term represents the "curvature information based upon a color component matching the color component at the interpolation target pixel" and the third term represents the "curvature information based upon a color component other than the color component at the interpolation target pixel", the

third term constitutes the "curvature information based upon the blue color component" if color information corresponding to the red color component is present at the interpolation target pixel (FIG. 3(1)), whereas the third term constitutes the "curvature information based upon the red color component" if color information corresponding to the blue color component is present at the interpolation target pixel (FIG. 3(2)).

[0122]

In other words, the average information of the green color component (the primary term) is corrected by using the curvature information based upon the red color component and the curvature information based upon the blue color component at phases opposite from each other in the second embodiment.

As a result, as in the first embodiment, even when the color information corresponding to the red color component and the color information corresponding to the blue color component are offset relative to the color information corresponding to the green color component due to a magnification chromatic aberration, the primary term is corrected in correspondence to the average change in quantity in the color information corresponding to the red color component and the color information corresponding to the blue color component in the second embodiment (see FIG.

9). Thus, even when there is a magnification chromatic aberration at the photographic optical system 12, the primary term can be corrected for a desired pixel with the overshoot and undershoot occurring in the G interpolation processing disclosed in USP No. 5,629,734 canceling out each other in the second embodiment. Consequently, the occurrence of color artifacts due to over correction can be reduced by adopting the second embodiment.

[0123]

(Third Embodiment)

The following is an explanation of the operation achieved in the third embodiment.

It is to be noted that since the RB interpolation processing in the third embodiment is implemented as in the first embodiment, its explanation is omitted.

In the following explanation of the G interpolation processing, operating details identical to those in the first embodiment are not explained. It is to be noted that the difference between the G interpolation processing in the third embodiment and the G interpolation processing in the first embodiment is in the operation performed after a judgment is made with regard to degrees of similarity manifested by the interpolation target pixel. For this reason, a flowchart of the operation performed at the interpolation processing unit 17 during the G

interpolation processing in the third embodiment is not provided.

[0124]

The interpolation processing unit 17 ascertains degrees of similarity manifesting by the interpolation target pixel as in the first embodiment (corresponds to FIG. 4 S1 ~ S11) and classifies the type of similarity at the interpolation target pixel as one of case 1 ~ 9 explained earlier.

Then, the interpolation processing unit 17 calculates the inclination Gk[i,j] of the green color component and the inclination Zk[i,j] of the red color component (or the blue color component) relative to the direction perpendicular to the direction judged to manifest marked similarity as indicated below.

[0125]

In case1,

Gk[i,j]=((G[i-1,j]+G[i,j-1])-(G[i,j+1]+G[i+1,j]))/2

··· formula 55

Zk[i,j]=((Z[i-2,j]+Z[i,j-2])-(Z[i,j+2]+Z[i+2,j]))/2

··· formula 56

In case2,

Gk[i,j]=G[i,j-1]-G[i,j+1] ··· formula 57

Zk[i,j]=Z[i,j-2]-Z[i,j+2] ··· formula 58

In case3,

Gk[i,j]=((G[i-1,j]+G[i,j+1])-(G[i,j-1]+G[i+1,j]))/2

… formula 59

Zk[i,j]=((Z[i-2,j]+Z[i,j+2])-(Z[i,j-2]+Z[i+2,j]))/2

… formula 60

In case 4, same as an case 1

In case 5,

Gk[i,j]=1, Zk[i,j]=1

In case 6, same as an case 3

In case 7, same as an case 1

In case 8

Gk[i,j]=G[i-1,j]-G[i+1,j] … formula 61

Zk[i,j]=Z[i-2,j]-Z[i+2,j] … formula 62

In case 9, same as an case 3

Next, the interpolation processing unit 17 calculates the green color interpolation value G[i,j] as follows.

[0126]

In case 1, G[i,j] = Gvk[i,j]

In case 2, G[i,j] = Gvk[i,j]

In case 3, G[i,j] = Gvk[i,j]

In case 4, G[i,j] = (Gvk[i,j] + Ghk[i,j])/2

In case 5, G[i,j] = (Gvk[i,j] + Ghk[i,j])/2

In case 6, G[i,j] = (Gvk[i,j] + Ghk[i,j])/2

In case 7, G[i,j] = Ghk[i,j]

In case 8, G[i,j] = Ghk[i,j]

In case 9, G[i,j] = Ghk[i,j], with

$$Gvk[i,j]=(G[i,j-1]+G[i,j+1])/2 + Gk[i,j]/Zk[i,j]\cdot(2\cdot Z[i,j]-Z[i,j-2]-Z[i,j+2])/4$$
… formula 63 and

$$Ghk[i,j]=(G[i-1,j]+G[i+1,j])/2 + Gk[i,j]/Zk[i,j]\cdot(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/4$$
… formula 64.

[0127]

In formulae 63 and 64, the first term represents the "average information of the green color component" which is equivalent to the primary term in formula 1 and formula 2. The second term is the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by a weighting coefficient (a value indicating the correlation between the inclination Gk[i,j] of the green color component and the inclination Zk[i,j] of the red color component (or the blue color component): Gk[i,j]/Zk[i,j]), and is equivalent to the correctional term.

[0128]

Namely, in the third embodiment, the average information of the green color component is corrected by using the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by the weighting coefficient.

Now, a problem that arises when calculating the correction value by simply adding the "curvature information based upon a color component matching the color component at the interpolation target pixel" without being multiplied by the weighting coefficient to the "average information of the green color component" is discussed.

[0129]

For instance, when color information corresponding to the green color component and color information corresponding to the red color component (or the blue color component) are provided as indicated by ● in FIG. 13 (when the values indicated by the color information corresponding to the green color component start to increase at a specific position and the values indicated by the color information corresponding to the red color component (or the blue color component) start to decrease at the same position), the "curvature information based upon a color component matching the color component at the interpolation target pixel" indicates a positive value. Thus, in such a case, if the "curvature information based upon a color component matching and the color component at the interpolation target pixel" is added to the "average information of the green color component" without first multiplying it with the weighting coefficient, the

"average information of the green color component", which should be corrected along the negative direction, becomes corrected in the positive direction as indicated by △ in FIG. 13, resulting in an overshoot.

[0130]

In other words, when color information corresponding to the green color component and the color information corresponding to the red color component (or the blue color component) change in opposite directions from a specific position at a color boundary, an overshoot or an undershoot occurs if the correctional term is calculated simply by adding the "curvature information based upon a color component matching the color component at the interpolation target pixel" to the "average information of the green color component" without first multiplying the "curvature information based upon a color component matching the color component at the interpolation target pixel" by the weighting coefficient.

[0131]

In the embodiment, if color information corresponding to the green color component and color information corresponding to the red color component (or the blue color component) are provided as indicated by ● in FIG. 13, the sign of the inclination Gk[i,j] corresponding to the green color component and the sign of the inclination

Zk[i,j] corresponding to the red color component (or the blue color component) are opposite from each other resulting in the weighting coefficient being a negative value. Thus, the "average information of the green color component" is corrected in the desired direction as indicated by □ in FIG. 13, preventing an overshoot or an undershoot from occurring.

[0132]

Consequently, the occurrence of color artifacts attributable to over correction at a color boundary is reduced in the third embodiment.

It is to be noted that while no restrictions are imposed with regard to the value of the weighting coefficient in the third embodiment, restrictions may be imposed to set the value of the weighting coefficient within a specific range to ensure that the correctional term does not become too large.

[0133]

For instance, the range for the weighting coefficient may be set; $|Gk[i,j]/Zk[i,j]| \leqq 5$.

(Fourth Embodiment)

The following is an explanation of the operation achieved in the fourth embodiment.

[0134]

It is to be noted that since the RB interpolation

processing in the fourth embodiment is performed as in the first embodiment, its explanation is omitted. However, in the fourth embodiment, color differences containing the red color component are interpolated for some of the pixels at which color information corresponding to the green color component is present through formula 51 and color differences containing the red color component are interpolated for the remaining pixels at which color information corresponding to the green color component is present and for pixels at which color information corresponding to the blue color component is present through formula 52, as in the second embodiment.

[0135]

Now, the G interpolation processing is explained.

In the fourth embodiment, in which the closest pixels at which color information corresponding to the green color component is present are set along the horizontal direction to a pixel to undergo the G interpolation processing as shown in FIG. 3, interpolation processing is achieved in the simplest manner by using the color information at the pixels set along the horizontal direction. Accordingly, the green color interpolation value G[i,j] is calculated in the fourth embodiment as in case 8 in the third embodiment.

[0136]

Namely, the interpolation processing unit 17 calculates the green color interpolation value G[i,j] through formula 65.

$$G[i,j]=(G[i-1,j]+G[i+1,j])/2 +Gk[i,j]/Zk[i,j]\cdot(2\cdot Z[i,j]-Z[i-2,j]-Z[i+2,j])/4 \quad \cdots \text{ formula 65, with}$$

$$Gk[i,j]=G[i-1,j]-G[i+1,j] \quad \cdots \text{ formula 61 and}$$

$$Zk[i,j]=Z[i-2,j]-Z[i+2,j] \quad \cdots \text{ formula 62.}$$

[0137]

As indicated above, in the fourth embodiment, the average information of the green color component is corrected by using the "curvature information based upon a color component matching the color component at the interpolation target pixel" multiplied by the weighting coefficient (a value representing the correlation between the inclination Gk[i,j] corresponding to the green color component and the inclination Zk[i,j] corresponding to the red color component (or the blue color component): Gk[i,j]/Zk[i,j]) as in the third embodiment. As a result, the occurrence of color artifacts attributable to over correction at a color boundary can be reduced through the fourth embodiment.

[0138]

(Fifth Embodiment)

The following is an explanation of the operation

achieved in the fifth embodiment.

FIG. 14 is a functional block diagram representing the fifth embodiment.

It is to be noted that the fifth embodiment corresponds to interpolation processing executed by a personal computer by using the recording medium having recorded therein an interpolation processing program according to one of claims 21-25.

[0139]

In FIG. 14, the same reference numbers are assigned to components achieving identical functions to those in the functional block diagram in FIG. 1 to preclude the necessity for repeated explanation of their structures.

The structure of an electronic camera 20 shown in FIG. 14 differs from that of the electronic camera 10 in FIG. 1 in that a control unit 21 and an image processing unit 22 in FIG. 14 replace the control unit 11 and the image processing unit 15 in FIG. 1, with an interface unit 23 in FIG. 14 provided as an additional component.

[0140]

In addition, in FIG. 14, a personal computer 30 is provided with a CPU 31, an interface unit 32, a hard disk 33 and a memory 34 with the CPU 31 connected to the interface unit 32, the hard disk 33, the memory 34, the CD-ROM drive device 35 and the communication interface

unit 36 via a bus.

It is to be noted that an interpolation processing program (an interpolation processing program for executing interpolation processing similar to that implemented at the interpolation processing unit 17 in the various embodiments explained earlier) recorded at a recording medium such as a CD-ROM 37 is pre-installed at the personal computer 30 via the CD-ROM drive device 35. In other words, the interpolation processing program is stored at the hard disk 33 in an execution-ready state.

[0141]

The following is an explanation of the operation achieved in the fifth embodiment, given in reference to FIG. 14.

First, image data generated as in the electronic camera 10 shown in FIG. 1 are provided to the image processing unit 22 in the electronic camera 20. The image data undergo image processing (e.g., gradation conversion processing) other than interpolation processing at the image processing unit 22, and the image data having undergone the image processing are then recorded at the recording unit 16 in an image file format.

[0142]

This image file is provided to the personal computer 30 via the interface unit 23.

Upon obtaining the image file via the interface unit 32, the CPU 31 in the personal computer 30 executes the interpolation processing program.

Namely, interpolation processing similar to that achieved in the embodiments explained earlier is implemented on the personal computer 30 in the fifth embodiment.

[0143]

[Effect of the Invention]

As described above, the interpolation value is calculated by correcting the "average information of the first color component" with the "curvature information based upon a color component matching the color component at the interpolation target pixel" and the "curvature information based upon a color component other than the color component at the interpolation target pixel" in the inventions according to claims 1, 4 and 21. As a result, the occurrence of color artifacts attributable to over correction can be reduced.

[0144]

In the inventions according to claims 2, 3, 5-8 and 22, the interpolation value is calculated by using color information at pixels located along a plurality of directions in correspondence to the degrees of similarity to the interpolation target pixel. In particular, the

similarity manifesting along the diagonal directions is reflected in the interpolation value calculated in the inventions according to claims 5-8.

As a result, by adopting any of the inventions according to claims 2, 3, 5-8, the interpolation value can be calculated without loss of information related to the structure of the image.

[0145]

The adverse effect of the noise can be reduced in the judgment of the similarity in the invention according to claim 9, color information corresponding to a plurality of color components is reflected in the judgment of similarity in the invention according to claims 10 and 11 and the continuity with nearby pixels is reflected in the judgment of similarity in the invention according to claim 12.

As a result, by adopting any of the invention according to claims 9-12, the accuracy of the similarity judgment is improved.

[0146]

The direction along which correction is implemented and the width of the correction can be adjusted through the use of a weighting coefficient by correcting the "average information of the first color component" with the "curvature information based upon a color component

matching the color component at the interpolation target pixel" multiplied by the weighting coefficient in the inventions according to claims 13, 14 and 23. In particular, in the invention according to claim 14, in which the weighting coefficient is calculated in correspondence to the correlation among the inclinations of color information corresponding to the different color components in the area nearby the interpolation target pixel, the direction along which the correction is implemented and the width of the correction can be adjusted based upon the correlation when correcting the "average information of the first color component."

[0147]

Consequently, the occurrence of color artifacts attributable to over correction at a color boundary can be reduced by adopting the invention according to claim 13 or 14.

In any of the inventions according to claims 15-20, 24 and 25, the hue value of the interpolation target pixel is calculated by using the median of the hue values at a plurality of pixels located near the interpolation target pixel.

[0148]

Thus, the occurrence of color artifacts near an isolated point can be reduced without losing the color

structure by adopting any of the inventions according to claims 15-20. In addition, the interpolation value can be calculated quickly compared to the interpolation processing in the prior art (the processing achieved by combining RB interpolation processing and median processing).

[Brief Description of the Drawings]

[FIG. 1] FIG. 1 is a functional block diagram of an electronic camera corresponding to first through fourth embodiments;

[FIG. 2] FIG. 2 shows the arrangements of the color components in the image data adopted in the first embodiment and the third embodiment;

[FIG. 3] FIG. 3 shows the arrangements of the color components in the image data adopted in the second embodiment and the fourth embodiment;

[FIG. 4] FIG. 4 is a flowchart (1) of the operation achieved at the interpolation processing unit in the first embodiment;

[FIG. 5] FIG. 5 is a flowchart (2) of the operation achieved at the interpolation processing unit in the first embodiment;

[FIG. 6] FIG. 6 illustrates methods of weighted addition of similarity degree components;

[FIG. 7] FIG. 7 shows the directions along which marked

similarity manifests in correspondence to values (HV[i,j], DN[i,j]);

[FIG. 8] FIG. 8 shows the positions of the color information used to calculate the green color interpolation value G[i,j];

[FIG. 9] FIG. 9 shows how the adverse effect of magnification chromatic aberration is eliminated;

[FIG. 10] FIG. 10 illustrates median processing of the prior art;

[FIG. 11] FIG. 11 illustrates the median processing operation achieved in the first embodiment;

[FIG. 12] FIG. 12 illustrates the ranges of the median processing implemented in the first embodiment;

[FIG. 13] FIG. 13 illustrates the function of the weighting coefficient in the third embodiment;

[FIG. 14] FIG. 14 is a functional block diagram of a fifth embodiment;

[FIG. 15] FIG. 15 illustrates an example of the interpolation processing in the prior art;

[FIG. 16] FIGS. 16 illustrates the adverse effects of magnification chromatic aberration;

[FIG. 17] FIGS. 17 illustrates over correction occurring due to magnification chromatic aberration; and

[FIG. 18] FIGS. 18 illustrates the effects of over correction occurring at a color boundary.

[Explanation of the reference numerals]

10, 20	an electronic camera
11, 21	a control unit
12	a photographic optical system
13	an image-capturing unit
14	an A/D conversion unit
15, 22	an image processing unit
16	a recording unit
17	an interpolation processing unit
23, 32	an interface unit
30	a personal computer
31	a CPU 31
33	a hard disk
34	a memory

[TITLE OF DOCUMENT] ABSTRACT OF DISCLOSURE

[ABSTRACT]

[PROBLEMS TO BE SOLVED]

An object of the present invention that relates to an interpolation processing apparatus that engages in interpolation processing on color image data to supplement a color component and a luminance component missing in pixels and a recording medium having an interpolation processing program for achieving the interpolation processing on a computer, that can be read by a computer, is that occurrence of color artifacts can be prevented.

[MEANS FOR SOLVING THE PROBLEMS]

An interpolation processing apparatus engages in processing on image data which are provided in a colorimetric system constituted of first ~ nth ($n \geqq 3$) color components and include color information corresponding to a single color component provided at each pixel to determine an interpolation value equivalent to color information corresponding to the first color component for a pixel at which the first color component is missing, and includes: a means for interpolation value calculation that uses color information at nearby pixels located nearby an interpolation target pixel to undergo interpolation processing to calculate an interpolation value including, at least a first term indicating local

average information with regard to the first color component, a second term indicating curvature information with regard to a color component matching a color component at the interpolation target pixel and a third term indicating curvature information with regard to a color component other than the color component at the interpolation target pixel.

[REFERENCE] FIG.4

FIG.1

A FUNCTIONAL BLOCK DIAGRAM OF AN ELECTRONIC CAMERA CORRESPONDING TO FIRST THROUGH FOURTH EMBODIMENTS

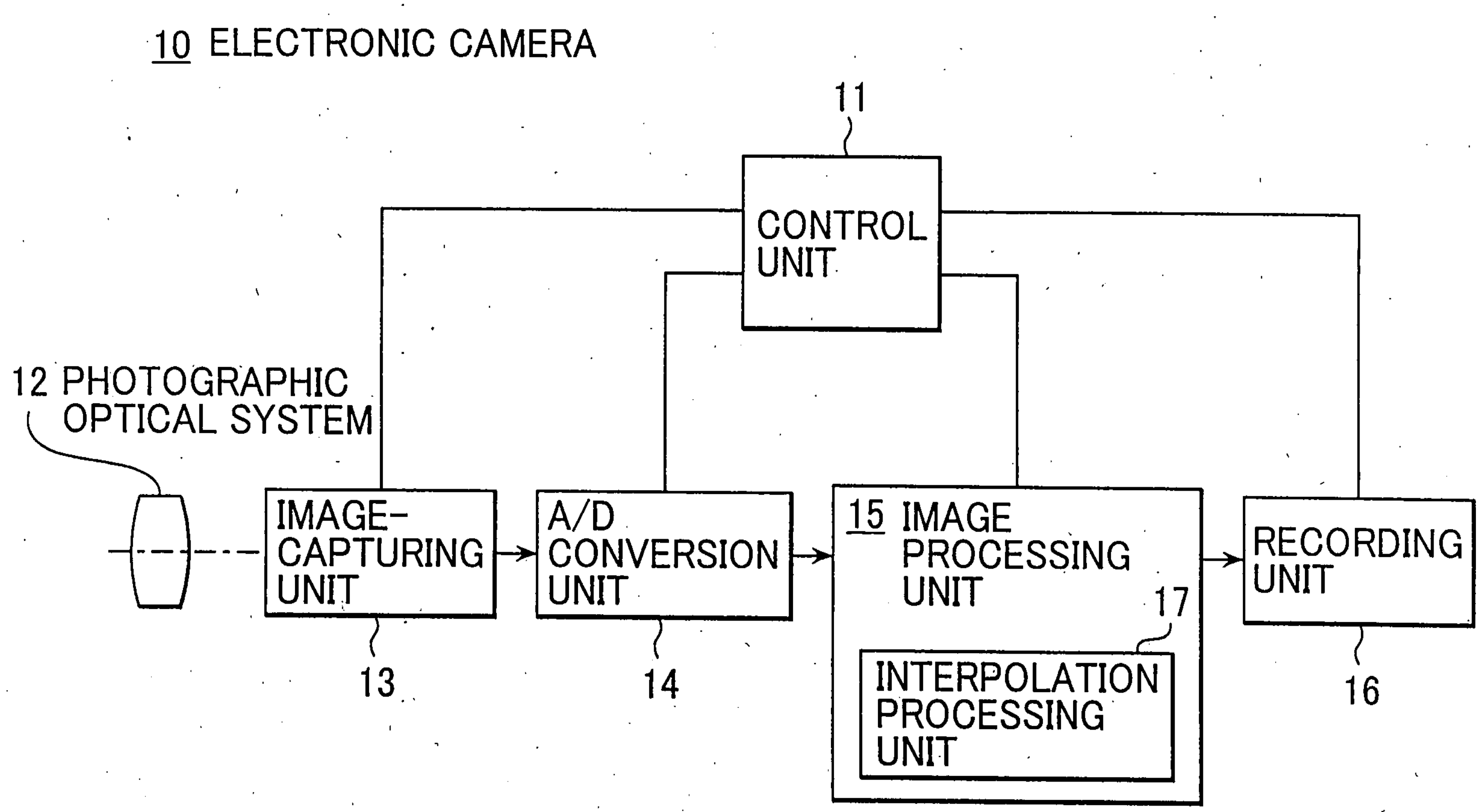


FIG.2

THE ARRANGEMENTS OF THE COLOR COMPONENTS IN THE IMAGE DATA ADOPTED IN THE FIRST EMBODIMENT AND THE THIRD EMBODIMENT

COORDINATES [i, j]	i−3	i−2	i−1	i	i+1	i+2	i+3
j−3	B	G	B	G	B	G	B
j−2	G	R	G	R	G	R	G
j−1	B	G	B	G	B	G	B
j	G	R	G	**R**	G	R	G
j+1	B	G	B	G	B	G	B
j+2	G	R	G	R	G	R	G
j+3	B	G	B	G	B	G	B

(1)

COORDINATES [i, j]	i−3	i−2	i−1	i	i+1	i+2	i+3
j−3	R	G	R	G	R	G	R
j−2	G	B	G	B	G	B	G
j−1	R	G	R	G	R	G	R
j	G	B	G	**B**	G	B	G
j+1	R	G	R	G	R	G	R
j+2	G	B	G	B	G	B	G
j+3	R	G	R	G	R	G	R

(2)

FIG.3 THE ARRANGEMENTS OF THE COLOR COMPONENTS IN THE IMAGE DATA ADOPTED IN THE SECOND EMBODIMENT AND THE FOURTH EMBODIMENT

COORDINATES [i, j]	i−2	i−1	i	i+1	i+2
j−2	R	G	R	G	R
j−1	B	G	B	G	B
j	R	G	**R**	G	R
j+1	B	G	B	G	B
j+2	R	G	R	G	R

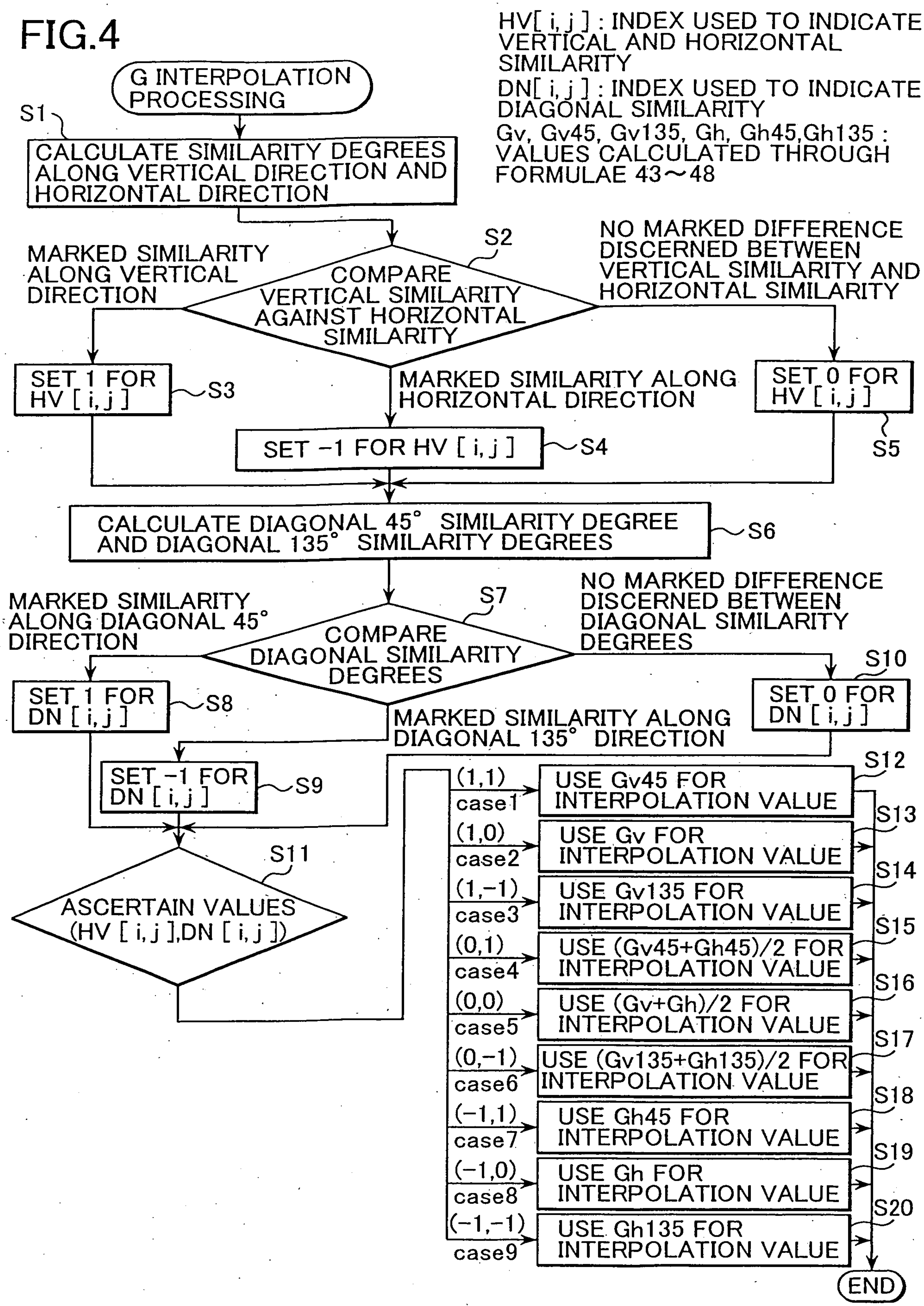
(1)

COORDINATES [i, j]	i−2	i−1	i	i+1	i+2
j−2	B	G	B	G	B
j−1	R	G	R	G	R
j	B	G	**B**	G	B
j+1	R	G	R	G	R
j+2	B	G	B	G	B

(2)

A FLOWCHART (1) OF THE OPERATION ACHIEVED AT THE INTERPOLATION PROCESSING UNIT IN THE FIRST EMBODIMENT

FIG.4



A FLOWCHART (2) OF THE OPERATION ACHIEVED AT THE INTERPOLATION PROCESSING UNIT IN THE FIRST EMBODIMENT

FIG.5

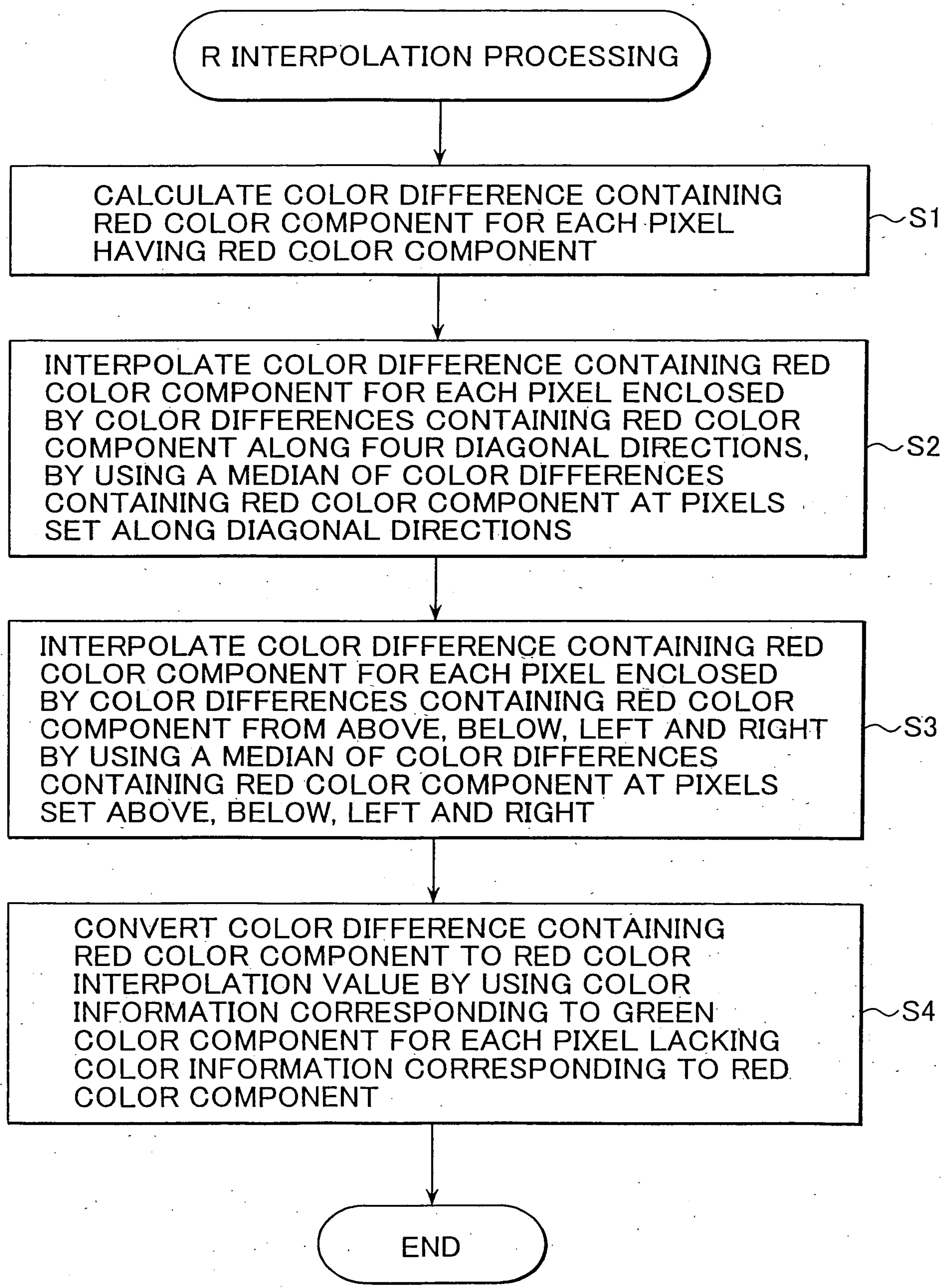


FIG.6 WEIGHTED ADDITION OF SIMILARITY DEGREE COMPONENTS

(1)

1		1
	4	
1		1

× 1/8

WEIGHTED ADDITION OF SIMILARITY DEGREE COMPONENTS IN METHOD 1

(2)

		1		
	2		2	
1		4		1
	2		2	
		1		

× 1/16

WEIGHTED ADDITION OF SIMILARITY DEGREE COMPONENTS IN METHOD 2

FIG.7 THE DIRECTIONS ALONG WHICH MARKED SIMILARITY MANIFESTS IN CORRESPONDENCE TO VALUES (HV[I, J], DN[I, J])

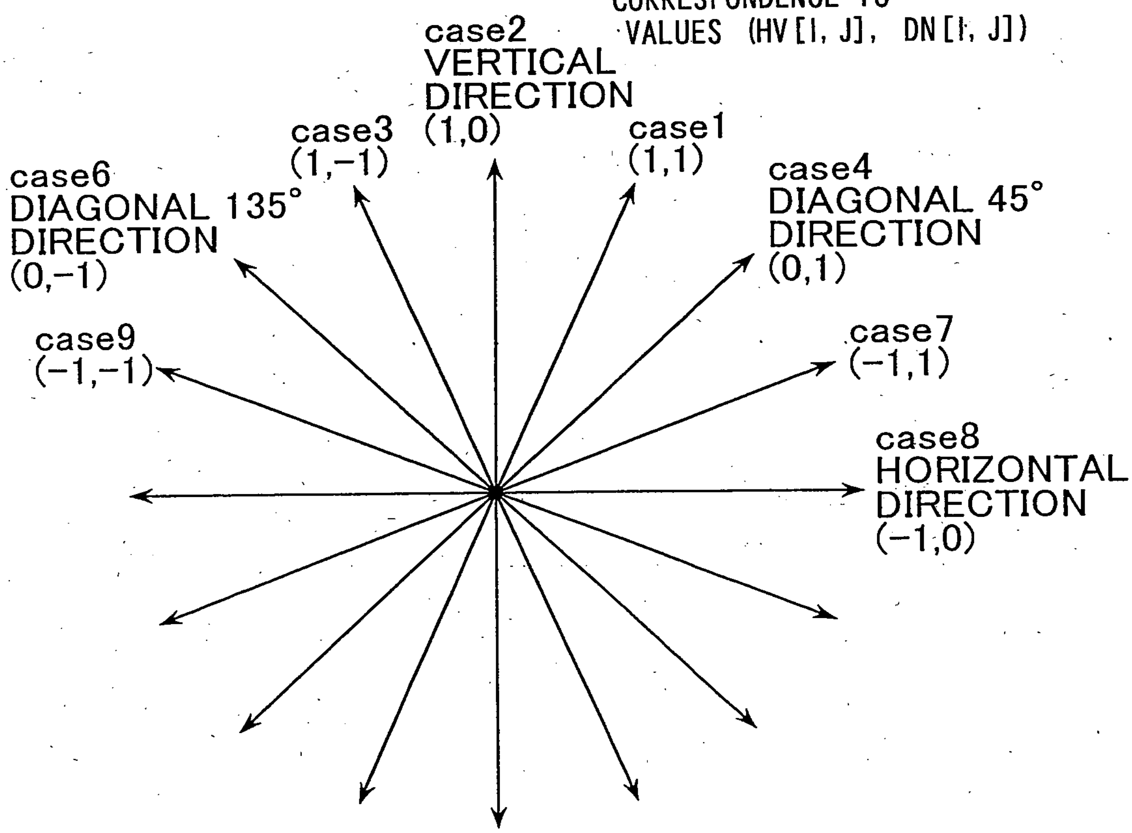


FIG.8

THE POSITIONS OF THE COLOR INFORMATION USED TO CALCULATE THE GREEN COLOR INTERPOLATION VALUE G[I, J]

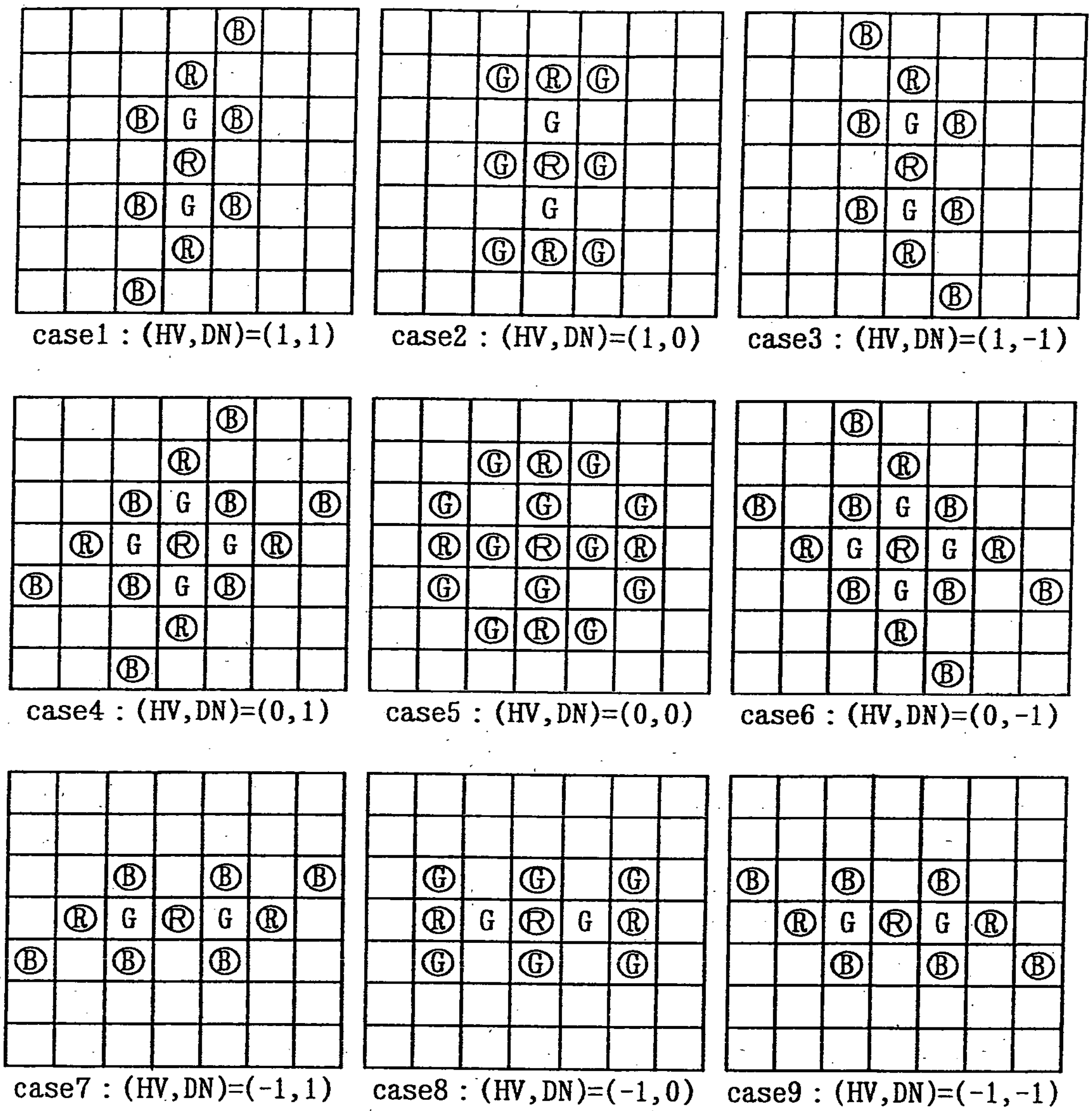


FIG.9

HOW THE ADVERSE EFFECT OF MAGNIFICATION CHROMATIC ABERRATION IS ELIMINATED

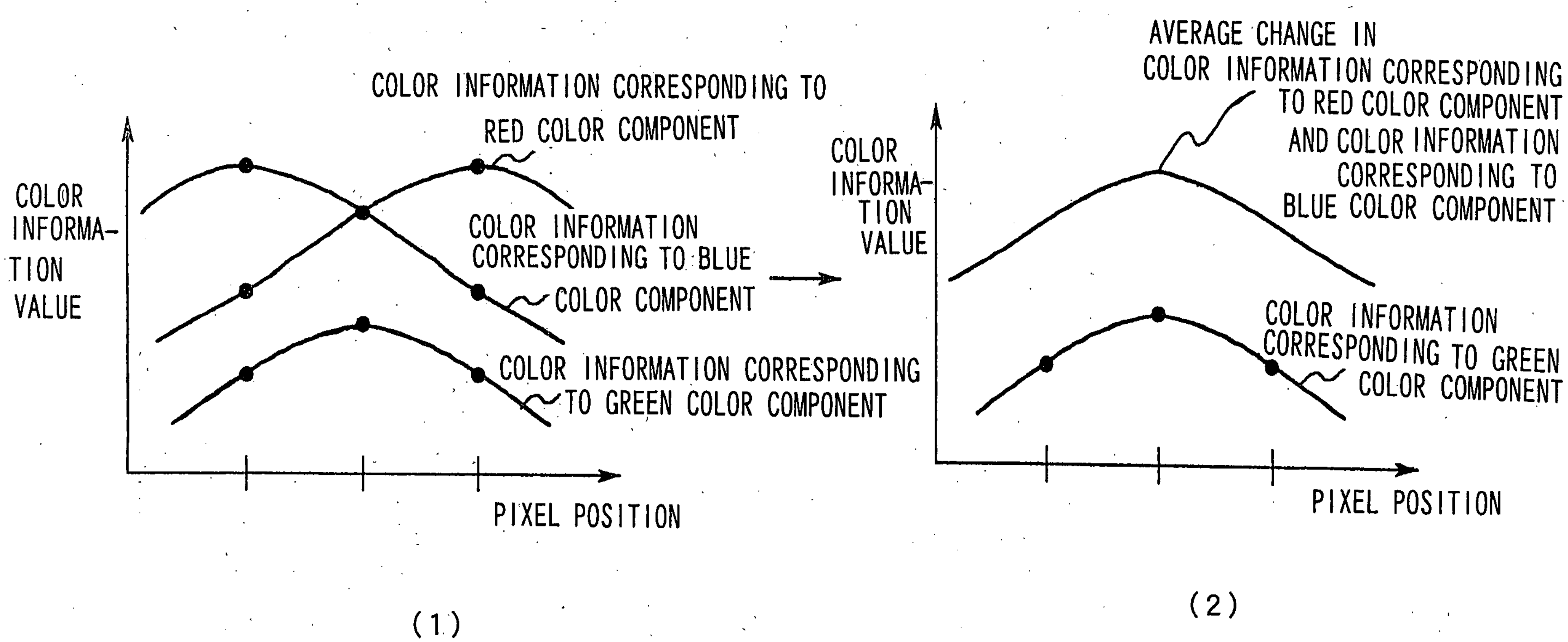


FIG.10

ILLUSTRATES MEDIAN PROCESSING OF THE PRIOR ART

Y	○	Y
△	×	△
Y	○	Y

(1)

Cr	○	Cr
△	×	△
Cr	○	Cr

(2)

Cb	○	Cb
△	×	△
Cb	○	Cb

(3)

FIG.11 ILLUSTRATES THE MEDIAN PROCESSING OPERATION ACHIEVED IN THE FIRST EMBODIMENT

COORDINATES [m,n]	m−1	m	m+1
n−1	Cr		Cr
n		×	
n+1	Cr		Cr

(1)

COORDINATES [m,n]	m−1	m	m+1
n−1		Cr	
n	Cr	×	Cr
n+1		Cr	

(2)

FIG.12 ILLUSTRATES THE RANGES OF THE MEDIAN PROCESSING IMPLEMENTED IN THE FIRST EMBODIMENT

Cr		Cr
	×	
Cr	○	Cr
	×	
Cr		Cr

(1)

Cr		Cr		Cr
	×	△	×	
Cr		Cr		Cr

(2)

FIG.13

ILLUSTRATES THE FUNCTION OF THE WEIGHTING COEFFICIENT IN THE THIRD EMBODIMENT

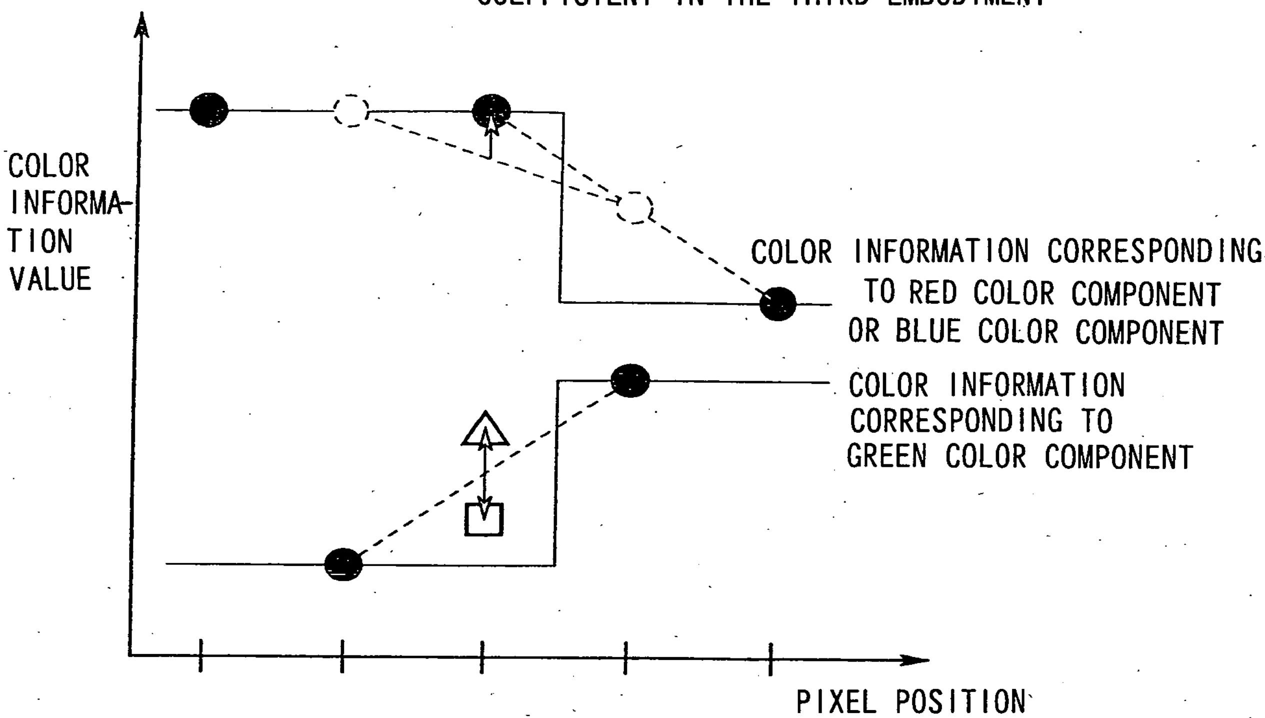


FIG.14

A FUNCTIONAL BLOCK DIAGRAM
OF A FIFTH EMBODIMENT

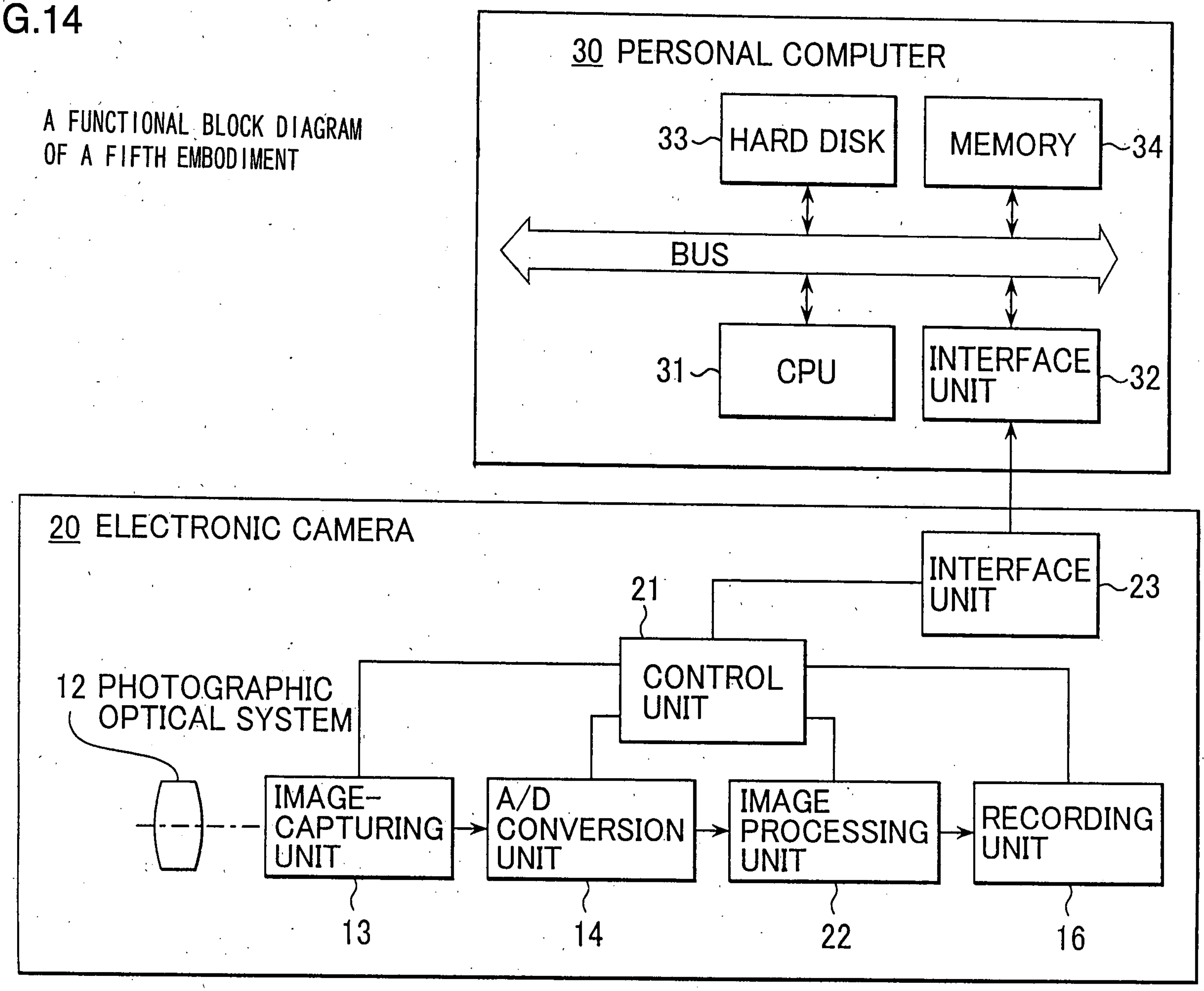


FIG.15

ILLUSTRATES AN EXAMPLE OF THE INTERPOLATION PROCESSING IN THE PRIOR ART

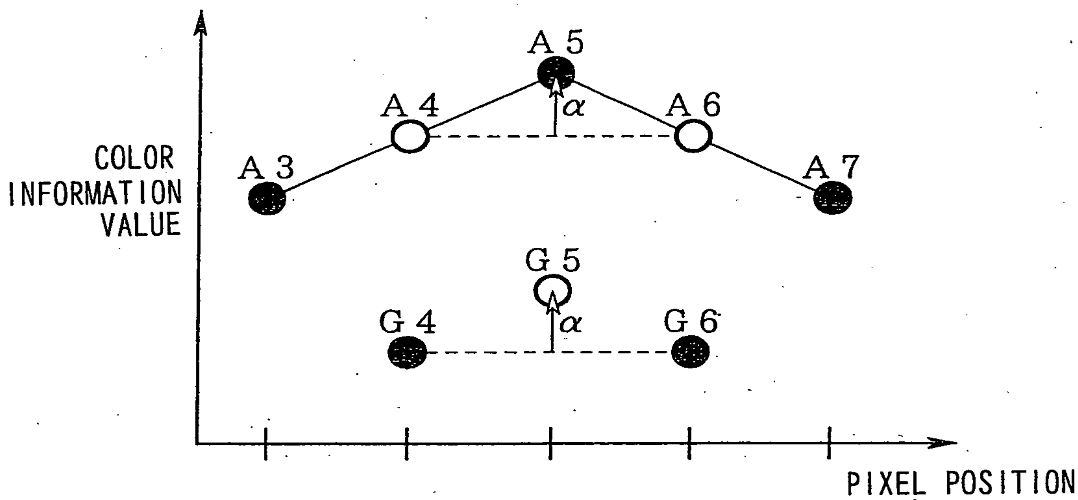


FIG.16

ILLUSTRATES THE ADVERSE EFFECTS OF MAGNIFICATION CHROMATIC ABERRATION

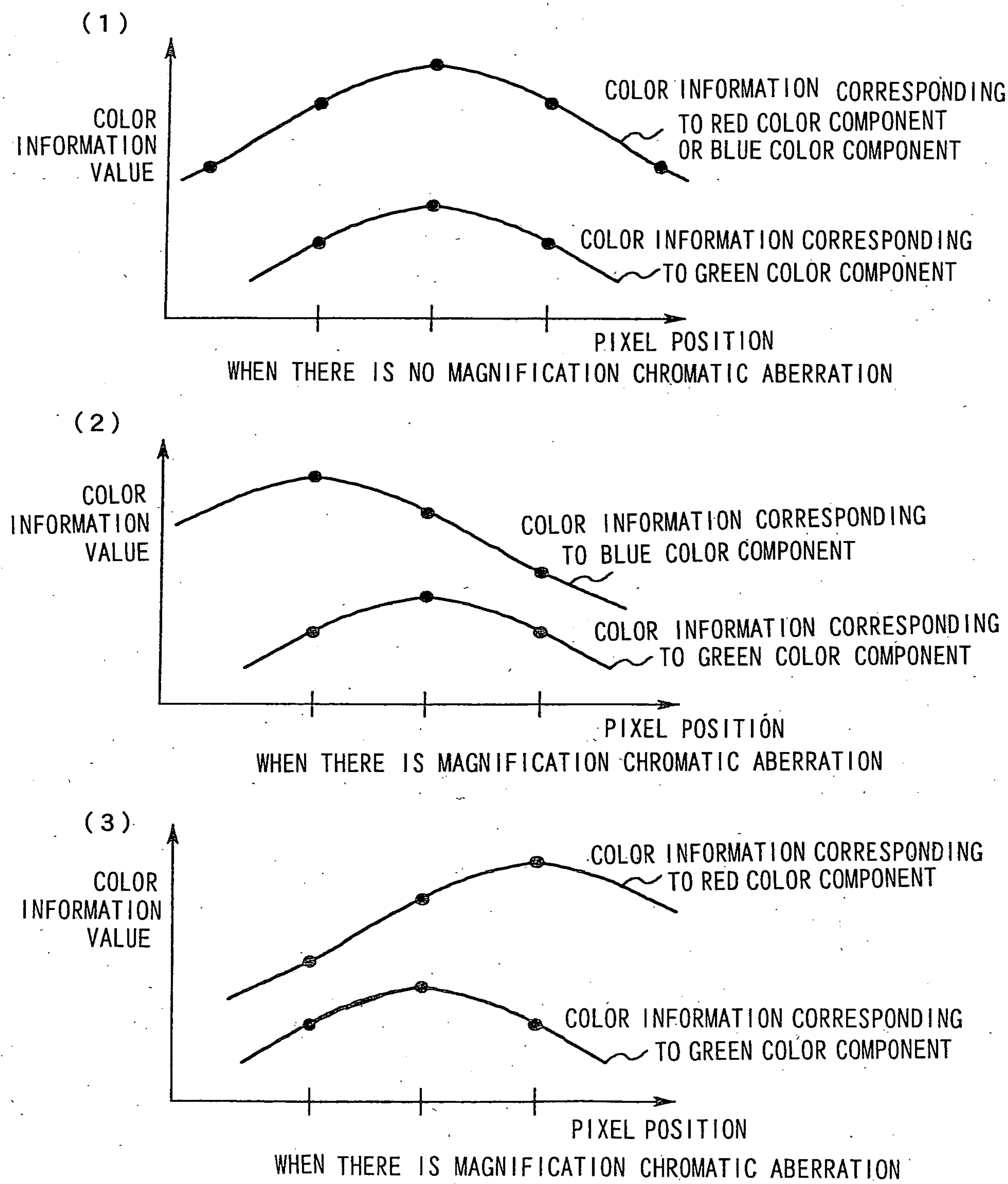


FIG.17

ILLUSTRATES OVER CORRECTION OCCURRING DUE TO MAGNIFICATION CHROMATIC ABERRATION

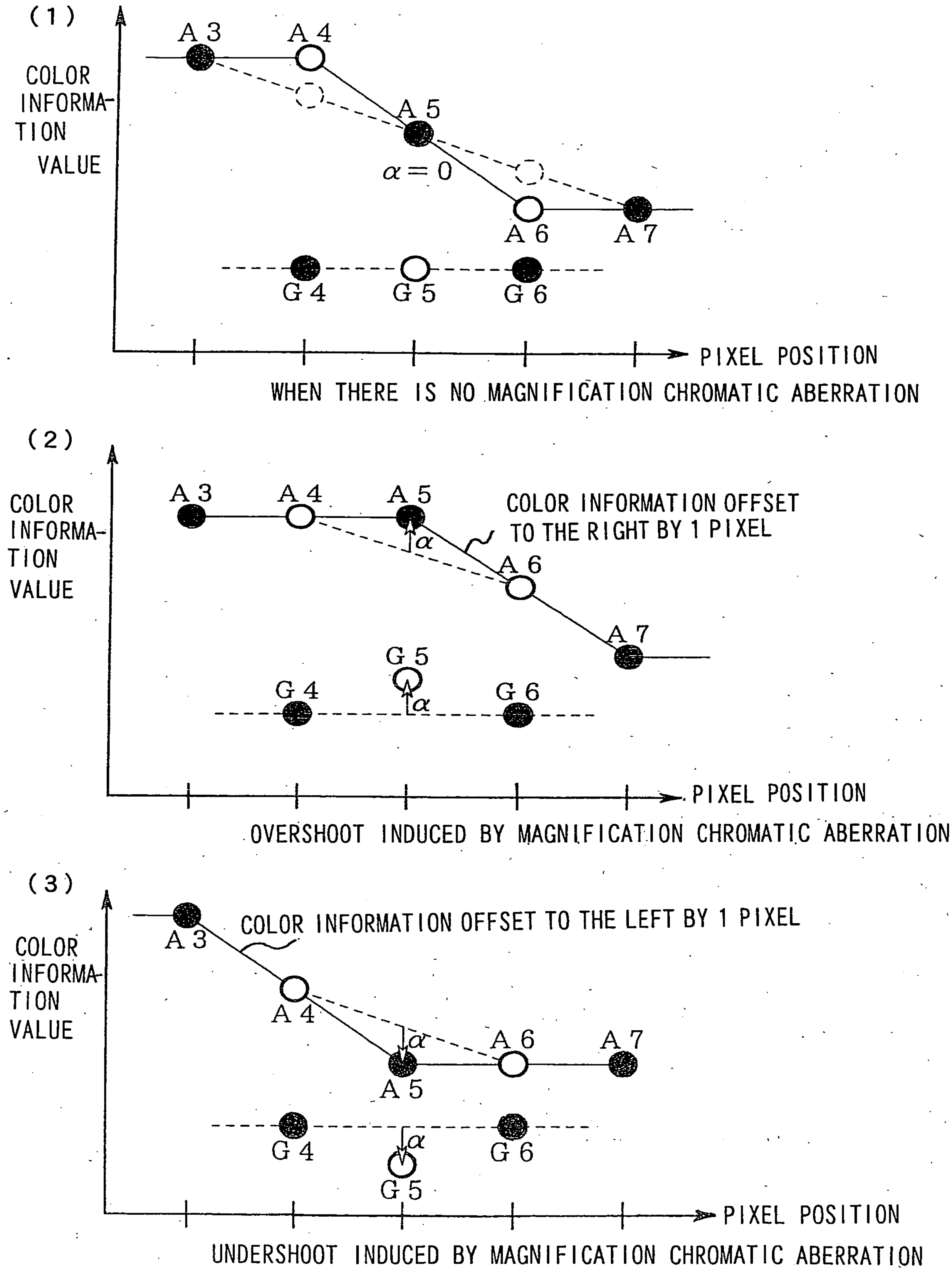
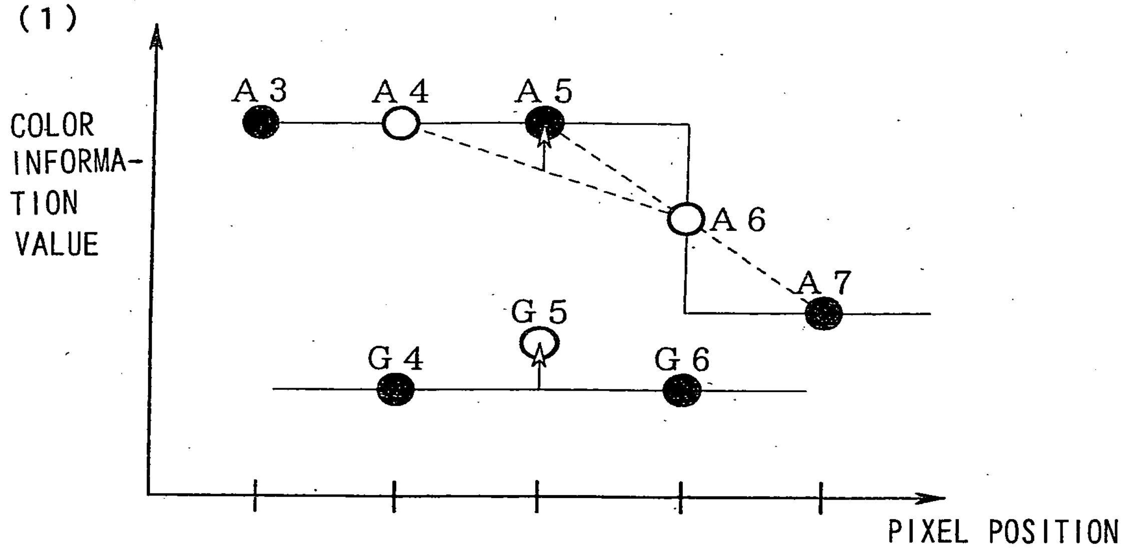


FIG.18

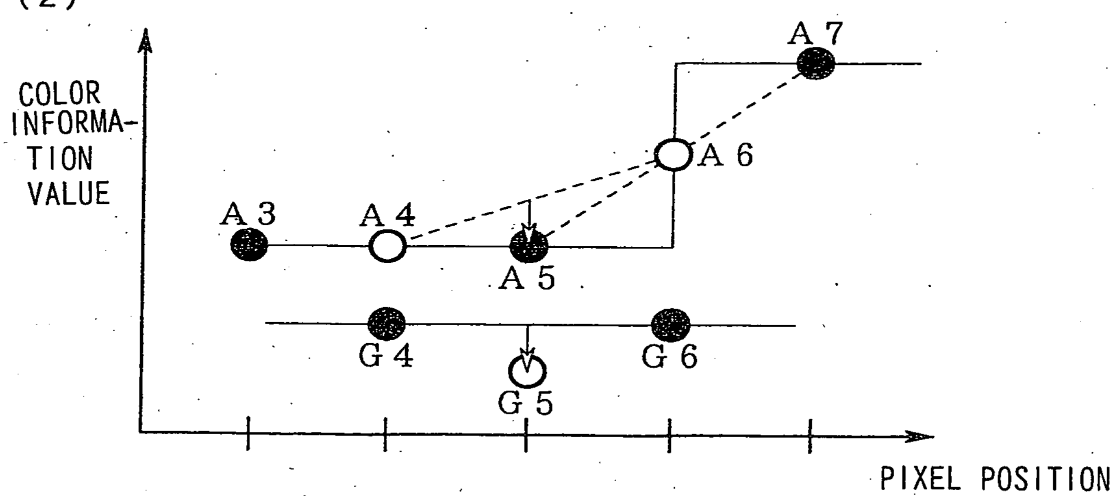
ILLUSTRATES THE EFFECTS OF OVER CORRECTION OCCURRING AT A COLOR BOUNDARY

(1)



OVERSHOOT INDUCING STATE

(2)



UNDERSHOOT INDUCING STATE